NICKEL

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For the past 20 years, nickel producers have been plagued by cyclical and widely swinging price fluctuations. Prices weakened between spring 1996 and yearend 1998, once again forcing producers to struggle to cut costs and to downsize operations. Several producers experienced sizable losses for the year. The spot price of nickel metal declined almost continuously throughout 1998. By yearend, the price had dropped to its lowest level for the century in terms of constant dollars. Several analysts attributed the 1996-98 price decline to recessionary forces in East Asia and the collapse of nickel consumption in the Russian Federation.

Despite weakening prices, producers continued to bring on new capacity because of optimistic forecasts for long-term growth in demand. More than 320,000 metric tons of capacity (on a contained nickel basis) were scheduled to come on-stream between 1999 and 2005. In Western Australia, three new laterite mines were in the final stages of commissioning, and at least three others were in various stages of development (Western Australian Department of Resources Development, 1999, p. 3-18). Some of the new Australian mines would refine the nickel on-site, and others would ship concentrates or matte to Outokumpu Oyj's recently expanded refinery in Finland. New mining projects were at various stages of development in Brazil, New Caledonia, Ontario, Quebec, and Venezuela. Since 1992, global nickel supplies have more than kept pace with growing demand for the metal in the Western World, and a short-term oversupply situation beginning in 2001 cannot be ruled out. Exports of primary nickel from Russia have remained firm, but consumption inside the country has plummeted. The recent financial crisis in Asia created problems for several major stainless steel producers and psychologically discouraged investment in nickel by commodity funds and banking houses.

Development of the huge Voisey's Bay nickel-copper-cobalt deposit in Labrador was still at a very early stage and was proceeding more slowly than anticipated because of the complex environmental review and approval process. The Voisey's Bay complex is the first major mining and milling project to be subjected to a full review under Canada's new Environmental Assessment Act. Favorable drilling reports from Voisey's Bay and the recent discovery of pentlandite mineralization in the Lac Rocher area of western Quebec spurred exploration for nickel sulfides throughout eastern Canada.

Russia continued to be the world's largest producer of nickel, with the bulk of its output coming from mines operated by RAO Norilsk Nickel in the Arctic. In 1998, Norilsk Nickel accounted for 96% of total Russian production. The newly privatized company continued to restructure all its mining and processing operations and produced slightly less nickel than in 1997.

In late 1997, QNI Limited of Australia purchased the nickel division of Billiton Plc after Billiton separated from Gencor Limited of South Africa. QNI funded the purchase by issuing a large block of new shares to Billiton, which gave Billiton a controlling interest of 52.5% in the enlarged QNI. Billiton later bought out the minority shareholders in QNI at a cost of $275 million and took control of the Australian company. The integration of QNI and Billiton Nickel created the fifth largest nickel producer in the world, with a market capitalization of about A$2 billion (QNI Limited and Billiton Plc, 1997, p. 16-34).

Stainless steel accounted for about 65% of primary nickel demand in the entire world. Another 5% was consumed in the production of alloy steels. During the past 20 years, stainless steel production in the West has grown at an average rate of 4.5%, down somewhat from the 50-year trend of 6% (Inco Limited, 1998d, p. 3-10).

In 1998, apparent U.S. demand for primary nickel was 149,000 tons, or 3% less than that of 1997. About 40% of the nickel was used to make austenitic stainless steel. U.S. demand for stainless steel was up slightly, with about 35% of the demand being met by imports. In 1997, U.S. stainless steel production reached a near-record high of 2.16 million tons despite a surge in imports. In 1998, stainless production decreased by 7% to 2.01 million tons (American Iron and Steel Institute, 1999a, p. 75). Several U.S. steel producers that were concerned about the growth in imports and loss of market share filed a series of countervailing duty and antidumping petitions with the U.S. Government.

On a per capita basis, the United States consumed significantly less stainless steel than Germany, Italy, Japan, the Republic of Korea, and Taiwan (Inco Limited, 1998d, p. 7). The European Union (EU) reported an increase of 4% in stainless steel production to 7.16 million tons—an output more than three times that of the United States. Japanese stainless steel production was down 15% because of economic problems in East Asia and reduced orders from China and other large Asian consumers (International Nickel Study Group, 1999c, p. 14). Still, Japan's output was 2.77 million tons, or 1.4 times that of the United States. In 1998, for the first time, the combined stainless steel production of the Republic of Korea and Taiwan exceeded that of the United States. Stainless steel production remained depressed in Russia because of that country's continuing economic restructuring.

Legislation and Government Programs

Cuban Embargo.—Efforts to normalize relations between Cuba and the United States continued to run into roadblocks. Importation of Cuban nickel is prohibited under the Cuban Assets Control Regulations, 31 CFR, part 515. The year began with some optimism on the part of Cuba observers, but this optimism quickly vanished (Rohter, 1999). On January 5, the President of the United States announced that several restrictions on U.S.-Cuban trade would be relaxed to encourage activities by Cuban charities affiliated with nongovernmental organizations. Subsequent political debate within the United States and the enactment of a new law in Cuba (The Law for the Protection of Cuba's National Independence and Economy), however, quickly returned relations to the "cold war" status quo. U.S. exports to Cuba continue to be restricted severely; most require licenses from the U.S. Department of the Treasury.

Despite the U.S. embargo, Cuban nickel production has been growing. In 1995, the Cuban nickel industry launched a major rehabilitation program with the help of foreign investors. (See section on Cuba.) The introduction of state-of-the-art technology and improved management practices has led to a sharp rise in productivity. Cuba has the largest reserve base of nickel-bearing laterites in the world. Nickel was being recovered at three mining and smelting complexes in Holguín Province. The Nicaro and Punta Gorda plants produced nickel oxide by the ammonium-carbonate leach process and were operated by La Compania General de Niquel S.A. (General Nickel), a parastatal enterprise. The third plant, Moa, produced a nickel-cobalt sulfide precipitate that was shipped to Canada for further processing. This third complex was operated as a joint venture of Sherritt International Corporation and General Nickel. The Cuban Government and Sherritt were equal partners in the Moa venture (Sherritt International Corporation, 1999, p. 6-7 and 18-20).

The Cuban Liberty and Democratic Solidarity (LIBERTAD) Act of 1996 (Public Law 104-114) codified existing Executive orders imposing an economic embargo on Cuba and discouraged foreign investment in Cuba (U.S. Department of Justice, 1996). In the press, the act is commonly referred to as the "Helms-Burton Law," after its Congressional authors. The law gave U.S. citizens who had property illegally expropriated by the Cuban Government on or after January 1, 1959, the right to sue in U.S. courts any foreign company that made use of the property. In addition, entry into the United States can be denied to foreign corporate officials and other principals found trafficking in expropriated Cuban properties. Sherritt executives have been barred from entering the United States under these provisions. In 1997, the EU, which disapproved of the LIBERTAD Act, responded by taking the matter of the Cuban embargo to the newly formed World Trade Organization; Canada and Mexico supported the EU's action.

On May 18, 1998, the United States and several members of the EU settled a series of longstanding disputes over U.S. sanctions against foreign companies doing business in Cuba, Iran, and Libya (Balz, 1998). As part of the settlement, the Clinton Administration agreed to seek changes from Congress that would give the President greater authority to waive certain economic sanctions against European countries doing business in Cuba. In exchange, the European countries would attempt to discourage future investment on the island (Lippman, 1998).

Environmental Regulations.—The Portable Rechargeable Battery Association, a nonprofit trade association comprising about 90 manufacturers, distributors, assemblers, users, and sellers of small rechargeable batteries, continued to expand its nationwide battery collection and recycling system. The nonprofit, public service recycling program was being administered by the Rechargeable Battery Recycling Corporation (RBRC) of Gainesville, FL. The RBRC was supported by more than 285 manufacturer/marketer licensees and a network of 26,000 collection locations across the United States and Canada. The bulk of the spent nickel-cadmium and nickel-metal hydride batteries were 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.

Many metropolitan areas of the United States continued to struggle with air-pollution problems and traffic congestion. The Federal Government, most of the 50 States, and many municipalities now have programs designed to reduce exhaust emissions from automobiles and other machinery self-propelled by internal combustion engines. California, Massachusetts, New York, and several other States have or were negotiating agreements with the automotive industry to encourage the development and sale of electric vehicles (EV's). Because of severe air-pollution problems in the Los Angeles Basin, California was in the forefront. Beginning in 2003, 10% of all automobiles sold in California must be EV's or some other type of zero-emission vehicle. Seven leading automobile manufacturers have signed agreements with the California Air Resources Board specifying EV sales targets and shipment deadlines (Evashenk, 1998, p. 3-4). The auto manufacturers also have agreed to begin selling low-emission vehicles—the so-called 49-State car—in 2001.

New Coinage.—The EU and the United States were in the process of issuing new coinage. The two Governments, however, have taken different positions with respect to nickel. The EU has limited nickel in its new coinage to minimize the potential risk of hypersensitive members of the public contracting nickel dermatitis. The U.S. Mint, however, will continue to use the cupronickel cladding now in circulation and apparently has received few complaints about the cladding causing nickel dermatitis. On December 1, 1997, the President signed into law legislation authorizing the minting during the next decade of some 2 billion to 3 billion nickel-bearing commemorative quarters (25-cent coins) per year; the new law was entitled The 50 States Commemorative Coin Program Act of 1997 (Public Law 105-124). The minting program will eventually honor each of the 50 States of the Union (Platt's Metals Week, 1997b).

The metal content, size, and shape of the new coin did not change. Like the previous "Eagle" quarter, the new coin contained 8.33% nickel and 91.67% copper. The coin has a core of pure copper and outer layers composed of a 25% nickel-75% copper alloy. Minting began on December 7, 1998. Five States are to be honored each year, beginning in 1999. The redesigned quarters are to be issued in the order in which the

States ratified the U.S. Constitution or were admitted into the Union. The first coins minted honored Delaware, Pennsylvania, New Jersey, Georgia, and Connecticut. The program was expected to earn from $3 billion to $5 billion for the Treasury.

The European Monetary Union was planning to have its new euro coinage in circulation by January 1, 2002. There were to be eight denominations—1, 2, 5, 10, 20, and 50 eurocent and 1 and 2 euro (Fortis Nederland, 1997a, p. 14; b). After July 1, 2002, coins of the individual member States would no longer be legal tender. Because of health considerations, the European Commission has proposed using a nickel-free alloy called Nordic Gold for the 10-, 20-, and 50-eurocent coins (Outokumpu Oyj, 1998a). The 1-, 2-, and 5-eurocent coins would also be nickel free (Outokumpu Oyj, 1998b). For technical reasons, the large 1- and 2-euro coins may contain some nickel. As mentioned earlier, environmental groups in Europe are concerned that long-term contact with coins made from nickel alloys could produce nickel dermatitis in some hypersensitive individuals. Minting of the first euro coinage began in 1998. An estimated 70 billion old national coins are currently circulating in the 15 member States of the EU. About 75% of the coins contain nickel. The changeover would cause this percentage to fall to 8%.

Defense Stockpile Sales.—The Defense Logistics Agency (DLA) continued to sell nickel from the National Defense Stockpile and had only 8,525 tons of nickel left at the beginning of 1998, all of which was metal. When the sales started on March 24, 1993, inventory totaled 33,760 tons of contained nickel. The ongoing sales are part of a much larger downsizing of the stockpile approved under The Defense Authorization Act of 1992 (Public Law 102-484). The nickel was being offered at monthly auctions and through privately negotiated long-term solicitations.

By the end of 1997, uncommitted stocks had shrunk to 3,227 tons. An additional 4,885 tons was awaiting pickup on December 31, 1997, for a total physical inventory of 8,525, including 413 tons of material unavailable for sale. In 1998, DLA warehouses turned over 5,927 tons to purchasers, leaving uncommitted stocks of 1,386 tons on December 31; this does not include 799 tons of committed material. All the remaining uncommitted stocks of nickel were sold in the first half of 1999.

Production

Primary Production.—In 1998, the United States had only one primary nickel producer—the Glenbrook Nickel Co. of Riddle, OR. The company was owned by Cominco American Inc., a subsidiary of Cominco Ltd. of Vancouver, British Columbia. Glenbrook was idled at the end of the first quarter, producing only 4,285 tons of nickel contained in ferronickel. The smelter had been using the Ugine reduction process to make high-grade granulated ferronickel from lateritic ores rich in garnierite. Since 1991, a large part of the ore fed to the smelter had come increasingly from Société Minière du Sud Pacifique (SMSP) of New Caledonia. After drying and calcination, the ore was smelted in four 24-megavolt-ampere open-arc electric furnaces. The Ugine process requires ferrosilicon, which is added to the molten nickel ore to promote rapid reduction of the nickel while still keeping a large part of the iron in oxide form. As a result, Glenbrook's ferronickel had a considerably higher nickel content (48% to 52%) than most competing products (19% to 41%).

In late 1997, Cominco Ltd. took steps to close the Oregon complex permanently when the world price fell below $6,000 per ton ($2.72 per pound). The last day of operation was March 30, 1998, which was the day existing ore stocks were exhausted. The company's port and ore-receiving facilities at Coos Bay were also shut down. About 305 employees lost their jobs as a result of the closure, seriously affecting the economy of Douglas County. Cominco officials stated that the action was taken because of the poor near-to-midterm outlook for nickel prices and an anticipated oversupply of nickel in coming years (Cominco Ltd., 1998; Kelly, 1998a). (See Prices section of this review.)

During 1997, the Glenbrook workforce made significant improvements in productivity, which reduced production costs (Robinson, 1998). Unfortunately, the cost cutting could not keep up with the drop in the London Metal Exchange (LME) price. One problem was the more-than 10,200-kilometer (5,500-nautical-mile) distance from New Caledonia to Coos Bay. Another problem was the economics of using ferrosilicon as a reductant to recover the nickel. Ferrosilicon production has been a major expense for Glenbrook, even though the complex has a dedicated 15-megavolt-ampere electric arc furnace that can produce 20,000 tons per year of 50% ferrosilicon. In recent years, part of the ferrosilicon production cost has been offset by a favorable power contract with the Bonneville Power Administration; the contract will expire on October 1, 2001 (Ryan's Notes, 1998b).

Cominco carried out an in-depth feasibility study of the Glenbrook operation before deciding to close the facility. Glenbrook's overall cost of producing ferronickel could conceivably be lowered to less than $2.00 per pound Ni and capacity could be increased by 50% if the existing ferronickel furnaces were replaced by carbothermic furnaces at an estimated cost of $100 million. In 1997, Glenbrook spent $1 million carrying out pilot scale and demonstration tests of the new furnace technology. A brief history of Glenbrook was published by Cleary (1998).

Secondary Production.—Inmetco, an Inco subsidiary, continued to produce nickel-chromium-iron remelt alloy at its metals recovery facility in Ellwood City, PA. The facility was set up in 1978 to reclaim chromium and nickel from emission control dusts, swarf, grindings, and mill scale—all wastes generated by the stainless steel industry. Because of subsequent improvements to the facility, Inmetco can accept a broad spectrum of other recyclable nickel- and/or chromium-bearing wastes, including filter cakes, plating solutions and sludges, catalysts, refractory brick, and spent batteries (Barozzi, 1997). The company can accept three types of spent nickel-based batteries—nickel-cadmium, nickel-metal hydride, and nickel-iron—but asks shippers to segregate the latter two from the nickel-cadmium batteries whenever feasible.

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

The Stillwater Mining Company operated a base-metals refinery adjacent to its precious-metals smelter at Columbus, MT. The 2-year-old refinery produced a byproduct copper-nickel-cobalt solution, which was shipped by truck to Canada where the three metals were eventually recovered (Stillwater Mining Company, 1998b, p. 1-17). The company has been mining three of the platinum-group metals (PGM)—palladium, platinum, rhodium—and gold since 1986 from the Stillwater Complex at Nye in Montana's Beartooth Mountains. The Nye mill was expanded in 1998 and processed 3,000 tons per day of ore (Stillwater Mining Company, 1999, p. 16-23). The PGM- and nickel-bearing sulfides in the ore are recovered by flotation and shipped as concentrate 74 kilometers to the company's smelter at Columbus. At Columbus, the concentrate is fed into a 1.5-megawatt electric furnace and made into matte. The furnace matte is remelted in one of two top-blown rotary converters to separate the bulk of the accompanying iron from the more valuable metals. The resulting iron-depleted converter matte is a mix of copper and nickel sulfides containing about 2% PGM by weight. The precious-metals smelter was expanded in 1997 and can now process up to 32 tons per day of concentrate.

At the refinery, the converter matte is leached with sulfuric acid to dissolve the nickel, copper, cobalt, and any remaining iron. The undissolved residue, which contains 55% to 60% platinum plus palladium, is pressure leached in autoclaves and made into a filter cake that can be sold to precious-metal refiners. At yearend, Stillwater began constructing a copper-nickel recovery circuit at its Columbus complex (Stillwater Mining Company, 1998a, p. 16-17). The copper-nickel recovery circuit cost about $6 million and was to come on-stream in late 1999.

In August 1998, Stillwater began to develop its East Boulder Project near Big Timber (Alexander, 1999). A 131-meter-long, 4.6-meter-diameter (430-foot-long, 15-foot-diameter) tunnel boring machine was being used to excavate a 5,640-meter-long (18,500-foot-long) adit to the J&M Reef. The boring machine was expected to reach the PGM-rich reef by January 2000. The company recently purchased a second tunneling machine and will use it to excavate a second parallel adit to provide additional access and ventilation.

Consumption

Demand for primary nickel in the West was down slightly from the all-time high of 942,000 tons (revised) of 1997 and was estimated to be about 935,000 tons (International Nickel Study Group, 1999b, p. 3-12; 1999c, p. 3-8). U.S. apparent consumption of primary nickel was 149,000 tons, or about 16% of Western demand. U.S. industry consumed an additional 63,300 tons of nickel in scrap.

Stainless Steel and Low-Alloy Steels.—In 1998, U.S. and world demand continued to be driven by the stainless steel industry. Stainless steel producers accounted for 40% of primary nickel demand in the United States and more than 60% of primary demand in the world. The percentage for the United States was lower because its stainless steel producers operated with higher scrap ratios than some of its foreign competitors. Also, a large part of the nickel consumed in the United States was used to make high-performance superalloys and related nickel-base alloys for the aerospace and petrochemical industries.

The world market for stainless steel has become increasingly competitive since 1985. Production of raw stainless steel in the West has doubled in the past 12 years, growing to 16.35 million tons in 1997 from 7.92 million tons in 1985 (Inco Limited, 1998d, p. 3-14). New production facilities have been started up in the Republic of Korea, South Africa, and Taiwan since 1990. At the same time, existing capacity has been expanded in Finland, France, Germany, Spain, and several other members of the EU. Stainless steel melting capacity in the West increased by 15% just between 1995 and 1997 at a time when East Asia and several other regions began experiencing severe financial problems and a slowing of their economies. This expansion of capacity has been accompanied by a globalization of markets for ferrous and nonferrous metals. Reduced growth in demand in several overseas markets has encouraged foreign stainless steel producers to increase their exports to the United States. Total U.S. imports of stainless steel mill products have grown by 136% since 1992, but domestic production has risen by only 11%. To remain competitive, the U.S. specialty steel industry has had to adopt more efficient work practices and to become extremely innovative. U.S. specialty steel producers are increasingly substituting quality for tonnage.

Despite these factors, production of raw stainless and heat-resisting steel in the United States decreased in 1998 by 7% to 2.01 million tons from the near-record high of 2.16 million tons reached in 1997. Nickel-bearing grades accounted for 1.18 million tons, or 59% of the total stainless production for 1998 (American Iron and Steel Institute, 1999b). Net shipments of all types of stainless totaled 1.85 million tons (American Iron and Steel Institute, 1999a, p. 22-29). Shipments of sheets and strip increased slightly to 1.38 million tons, breaking the previous record of 1.36 million tons set in 1997. The next largest category was plate [flat product 4.8 millimeters (3/16 inch) or more in thickness]. Shipments of plate were 219,000 tons, or 7% less than that of 1997. Together, plate and sheet accounted for 87% of total net shipments, slightly more than that of 1997.

Superalloys and Related Nickel-Base Alloys.—In 1998, U.S. consumption of primary nickel in superalloys was only slightly higher than that of 1997, which had been a good year for the superalloys industry. In 1997, consumption in superalloys increased by almost 20% because of growing orders in the aerospace industry. Jet engine manufacturers [e.g., General Electric Co., Pratt & Whitney Co., Inc. (subsidiary of United Technologies Corp.), and Rolls-Royce plc] are major consumers of nickel-chromium-cobalt and nickel-chromium-iron alloys. U.S. aerospace companies went through a difficult period from 1993 to 1995 because of declining defense spending, budget reductions at the National Aeronautics and Space Administration, and a protracted airline recession. In 1996, U.S. aerospace sales began to grow for the first time in 5 years. Sales rose by 8% after falling in 1995 to their lowest level in 9 years. Sales were even better in 1997 and jumped by 14% to $134 billion (revised). The aerospace market was shifting from a Government-dominated market to one driven primarily by commercial customers.

U.S. production of nickel-base alloys was down in December 1998 and January 1999 because of a softening of key markets and a labor dispute at the Inco Alloys International (IAI) plant in Huntington, WV. United Steelworkers of America Local 40 struck the facility on December 11, halting production (Sacco, 1999b). The strike ended on February 24, 1999, with labor and management agreeing to a 3-year contract that will expire on February 22, 2002, (Special Metals Corporation, 1999). With the purchase of IAI from Inco on October 28, 1998, Special Metals Corporation became the world's largest and most diversified producer of high-performance nickel-base alloys. The U.S. Government accounted for only 50% of domestic aerospace products and services compared with 75% a decade ago. Passenger and freight traffic carried by world airlines have been increasing since 1993. In 1998, the U.S. aerospace industry earned a record $7.4 billion on sales of $140 billion (Napier, 1998). For the fourth year in a row, the Boeing Company and McDonnell Douglas Corp. built up their backlog of orders for civil jet transports. A total of 601 net orders for large civil jet transports was received in 1998, compared with 501 (revised) in 1997 (Aerospace Industries Association of America, Inc., 1999). Between 1997 and 1998, actual shipments also increased, rising from 374 aircraft to 559. On August 1, 1997, McDonnell Douglas merged with a subsidiary of Boeing. On December 31, 1998, the combined firms—operating under the name of The Boeing Company—had a backlog of 1,786 aircraft, up from 1,744 at yearend 1997.

Mergers, Acquisitions, and Closures.—In mid-1996, the specialty steel industry of the United States embarked on a major restructuring. U.S. superalloy producers, which have close ties to some of the specialty steel producers, quickly followed suit. In August 1996, Allegheny Ludlum Corporation and Teledyne Inc. merged to form one of the larger ferrous specialty metals producers in the world. Since then, there have been at least six significant mergers or similar types of acquisitions in the industry. The principal force driving the mergers and acquisitions has been the financial synergies created by the integration of similar specialty metals operations.

Bethlehem Steel Corporation Acquired Lukens Inc.—On May 29, 1998, Bethlehem Steel Corporation completed its acquisition of Lukens Inc. The merger significantly strengthened Bethlehem's position as the leading U.S. producer of carbon and alloy steel plate. Lukens had been a plate and stainless producer, specializing in stainless-clad and nickel-clad plate. The acquisition cost Bethlehem about $800 million (Bethlehem Steel Corporation, 1998b). Lukens' shareholders received about $335 million in cash and $215 million worth of Bethlehem common stock for a total equity value of $550 million. Bethlehem also assumed $250 million in debt. Lukens was renamed Bethlehem Lukens Plate. The new division was responsible for carbon and alloy plate operations at Coatesville and Conshohocken, PA, at Bethlehem's Burns Harbor Division in northern Indiana, and at Sparrows Point, MD, outside of Baltimore.

Bethlehem Lukens Plate initially had six plate mills with a combined production capacity of 2.3 million tons per year but closed two of the mills in late 1998; one of the plate mills shut down was at Coatesville; the other, at Sparrows Point. Increased use of the remaining four plate mills allowed the new division to continue to produce at the 2-million-ton level.

In December 1997, Lukens also received an acquisition proposal from Allegheny Teledyne Inc. After a brief period of intense bidding for the Coatesville-based plate producer, Bethlehem agreed to sell most of Lukens' stainless steel operations to Allegheny Teledyne; the exception was the plate operations.

On January 28, 1998, Bethlehem and Allegheny Teledyne signed three agreements linked to Bethlehem's acquisition of Lukens. First, Allegheny Teledyne was to pay Bethlehem $175 million for three of Lukens' facilities manufacturing stainless steel—the electric furnace melt shop and hot-rolling operations at Houston, PA, the annealing and pickling line at Massillon, OH, and the vacuum-oxygen-decarburization refining unit at Coatesville. Second, Bethlehem Lukens Plate was to provide Allegheny Teledyne with conversion services to make stainless steel hot bands and coiled plate wider than Allegheny Teledyne could produce. Bethlehem Lukens was to give Allegheny Teledyne exclusive access to the melt shop and stainless slab caster at Coatesville (Bethlehem Steel Corporation, 1998a; Boselovic, 1999a); access was guaranteed for 20 years. The output was to be processed at Bethlehem Lukens' 110-inch Steckel mill in Conshohocken. Third, Bethlehem announced that it had no intention of continuing in the stainless steel sheet business and would try to find buyers for the remaining Lukens' stainless steel operations at Washington, PA, and Massillon, OH. To provide continuity to these operations until they were sold, Allegheny Teledyne agreed to supply stainless hot roll bands to Bethlehem Lukens for an undisclosed period (Bethlehem Steel Corporation and Allegheny Teledyne Inc., 1998). The two companies finalized their agreements in November and announced that they would jointly upgrade the Conshohocken Steckel mill. The upgrading of the Steckel mill, which rolls stainless steel slabs and different types of nickel alloys, was expected to cost $25 million.

On January 7, 1999, Bethlehem announced that it would permanently close the stainless steel operations at Washington, PA, and at Massillon, OH. About 340 workers were laid off at the Washington facility, and another 200 at Massillon (Boselovic, 1999b; Sacco, 1999a). Bethlehem decided to close the two facilities because of their recent operating cash losses and the company's concerns over unprecedented levels of foreign steel imports. The stainless sheet and strip operations also did not fit well into Bethlehem's core strategy of producing carbon and alloy steel products (Bethlehem Steel Corporation, 1998c, 1999). The Washington mill was operated in tandem with a melt shop and hot rolling facilities at Houston when all three facilities were owned by Lukens.

Allegheny Teledyne Inc. Restructured.—On January 19, 1999, Allegheny Teledyne announced that it would reconfigure the company. Four business units in the Aerospace and Electronics Segment were eventually spun off and welded into a new company that was to focus on high-technology products for the aerospace and communications industries. The four units were originally part of Teledyne and were absorbed when Teledyne merged with Allegheny Ludlum in August 1996 (Kuck, 1999, p. 53.6). In 1998, the Aerospace and Electronics Segment had annual sales of $1.01 billion. Allegheny Teledyne's Consumer Segment was also spun off and formed into a freestanding company. This segment had sales of $0.25 billion in 1998 (Allegheny Teledyne Inc., 1999; Boselovic, 1999c). The remaining units of Allegheny Teledyne were to focus on the specialty metals business and had combined sales of $2.57 billion.

J&L Specialty Steel, Inc. Became a Wholly Owned Subsidiary of the Usinor Group.—On December 17, the Usinor Group completed its acquisition of J&L Specialty Steel, Inc. (American Metal Market, 1998; Skillings Mining Review, 1998). Usinor, a French-based steel producer, has had a financial interest in J&L and its predecessor, J&L Specialty Products Corp., since June 1990. In mid-1998, Usinor owned 53.5% of J&L's common stock. On September 23, Usinor had offered to acquire the remaining outstanding shares of J&L and announced that it wanted to make J&L a wholly owned subsidiary of Usinor. On December 11, J&L accepted Usinor's cash tender offer of $6.25 per share. The successful tender increased Usinor's equity in J&L to 97.8%.

J&L was a leading U.S. manufacturer of flat rolled stainless steel. The company was headquartered in Pittsburgh, PA, and had plants at Midland, PA, Louisville, OH, and Detroit, MI. The Midland melt shop had two 100-metric-ton, ultra-high-power electric arc furnaces and an argon-oxygen-decarburization vessel. The casting shop had a single continuous slab caster capable of producing slabs from 0.66 to 1.57 meters (26 to 62 inches) in width. Three different slab thickness could be produced—156, 191, and 254 millimeters (6-c, 7-½, or 10 inches). The two electric furnaces, which were installed in 1980 when the plant was owned by Crucible, Inc., were able to produce about 40,000 metric tons per month of austenitic or ferritic stainless steel. The austenitic slabs were being rolled at the hot strip mill of LTV Steel Co., Inc. in Cleveland, OH, and the ferritic ones, at the hot strip mill of Weirton Steel Corp. in Weirton, WV. The rolled bands were then returned to J&L for finishing at Midland, Louisville, or Detroit (J&L Specialty Products Corp., 1992).

Operations of Republic Engineered Steels, Inc. and Bar Technologies, Inc. To Be Combined.—On July 24, 1998, Republic Engineered Steels, Inc., announced that it was being acquired by an affiliate of Blackstone Capital Partners II Merchant Banking Fund L.P. and Veritas Capital Partners L.P. The Blackstone-Veritas affiliate agreed to pay $7.25 cash for each share of Republic common stock. The offer equated to a total purchase price of $420 million after Republic's debts of about $277 million were included (Blackstone Group and Republic Engineered Steels, Inc., 1998).

Blackstone and Veritas intended to combine Republic's operations with those of Bar Technologies, Inc. (Sacco, 1998b). The combined company would have nearly 5,000 employees and sufficient capacity to produce about 20% of the bar steel consumed in the United States. Republic is a leading U.S. producer of carbon and alloy steel bars and has roots in the steel industry going back to 1886 (Gleisser, 1998). Republic is also a significant producer of stainless steel, tool steels, and remelted specialty steels. In 1998, it had 10 operating facilities with 3,800 employees in 6 States.

Bar Tech produced hot rolled engineered and cold finished steel bar products. The company was based in the Cleveland suburb of Seven Hills and was jointly owned by Blackstone and Veritas. Bar Tech was created in 1994 from what was once the Bar, Rod, and Wire Division of Bethlehem.

In November 1997, Republic entered into a 4-year technical exchange agreement with Sanyo Special Steel Co. Ltd. of Himeji, Japan. Sanyo, a pioneer in rapid melt technology, has been helping Republic streamline operations at its melt shop in Canton Township. During summer 1998, Danieli & C.S.p.A. of Buttrio, Italy, installed a $9 million ultra-high-power furnace incorporating Sanyo technology in the Canton facility. The new 200-metric-ton furnace was expected to shorten melt time from about 210 minutes to 100, thus sharply reducing power costs.

Ispat International, N.V. Acquired Inland Steel Co.—On July 16, 1998, Ispat International, N.V., completed its acquisition of Inland Steel Co. Ispat had been negotiating with Inland Steel Industries, Inc., of Chicago, the parent company, for more than 5 months. The transaction was valued at $1.4 billion (Inland Steel Industries, Inc., 1998a, b). At the time of the acquisition, Inland, the sixth largest steel producer in the United States, had been making all of its raw steel at its Indiana Harbor Works in East Chicago, IN. Carbon and high-strength low-alloy steel grades accounted for about 99% of production (Inland Steel Co., 1998, p. 1-12).

Inland has been using nickel to protect many of its steels against corrosion. For example, the company has been offering a special coating to buyers of its cold rolled sheet. The two-layer coating improves the paintability and corrosion resistance of the sheet and is applied to the nonprime side of the steel. The first layer is a zinc-nickel-base alloy, which is electrolytically deposited on the steel and immediately treated with a chromate. The chromate layer is then coated with a 1-micron-thick epoxy-based finish to provide additional protection against corrosion. The company also has been using a patented nickel-flash treatment to improve dramatically the paintability and corrosion resistance of some of its other sheet steels.

Ispat was one of the faster growing steel producers in the world and had substantial steelmaking facilities in Mexico and Trinidad. The Rotterdam-based company also had significant operations in Canada, Germany, and Ireland. Ispat was part of the LNM Group, which had a total annual steelmaking capacity of 15 million tons. The LNM Group had two other main members—PT Ispat Indo of Indonesia and Ispat Karmet JSC of Kazakhstan.

Special Metals Corporation Acquired Inco Alloys International With the Help of Titanium Metals Corporation.—In early 1997, the management of Inco decided to focus on its core business—nickel mining—and to sell off its alloys group. On June 11, 1997, Inco announced that it had agreed to sell its alloy manufacturing division—IAI—to Blackstone Capital Partners II Merchant Banking Fund L.P. for approximately $410 million (Coplan, 1997; Inco Limited, 1997b; Ryan's Notes, 1997; Sacco, 1997, 1999b). The sale was to have closed in fall 1997, but it encountered opposition from antitrust examiners in the U.S. Department of Justice. Blackstone, a merchant bank based in New York, owned approximately 80% of Haynes International Inc., a major IAI competitor. Because of the antitrust obstacles, Inco and Blackstone halted negotiations, and Inco began searching for another buyer for IAI.

On July 9, 1998, Inco agreed to sell IAI to Special Metals for \$408 million in cash (Inco Limited, 1998c). Special Metals was one of the world's leading producers of nickel-base alloys for jet engines. IAI and Special Metals, however, had relatively few overlapping markets so antitrust concerns were less of an issue than the previously proposed sale to Blackstone (Kelly, 1998b; Sacco, 1998c). On October 28, Inco and Special Metals went to settlement. The acquisition put an end to more than 16 months of uncertainty about the future of the former Inco business unit. Special Metals ended up paying Inco only \$365 million for IAI. Inco received convertible preferred shares of Special Metals valued at \$17 million as part of the \$365 million purchase. Special Metals also transferred a block of preferred stock valued at \$80 million to Titanium Metals Corporation (TIMET). Special Metals and TIMET agreed to form a strategic alliance aimed at jointly developing new uses for nickel-base alloys and titanium alloys. The acquisition made Special Metals the world's largest and most diversified producer of high-performance nickel-base alloys (Special Metals Corporation, 1998a, b).

Special Metals was also a leading manufacturer of superalloys, but had a more limited customer base than IAI. More than 80% of Special Metals' superalloys production was being sold to companies that fabricated or cast the material into parts for jet aircraft engines or powerplant gas turbines. The bulk of the company's products were being made by double vacuum melting and sold as bar or billet. The company was perhaps best known for its UDIMET family of superalloys, most of which have a nickel base. Special Metals also made NITINOL, a nickel-titanium shape memory alloy that is used by surgeons and orthodontists because of its biocompatibility and superelasticity. The company was based in New Hartford, NY, and had additional manufacturing facilities in Dunkirk, NY, Princeton, KY, and Ann Arbor, MI. The acquisition of IAI lessened Special Metals' dependence on highly cyclical aerospace sales and gave the company a broader, more diversified customer base (Ryan's Notes, 1998c; Special Metals Corporation, 1998b). Credit Lyonnais served as lead banker in the transaction.

Because of the acquisition, Special Metals has had to change its entire marketing strategy. The new company will be in a better position to offer a wider range of product forms and sizes to a much broader spectrum of end users. In 1998, nonaerospace revenues were expected to be 61% of total sales compared with only 19% prior to the acquisition. Special Metals now has more than 5,000 customers. Its largest customer accounts for less than 9% of net sales, down from 20% prior to the acquisition.

KB Alloys, Inc., Moved To Acquire Reading Alloys, Inc.—KB Alloys, Inc., reportedly signed a letter of intent to purchase Reading Alloys, Inc. (Ryan's Notes, 1998a). Both companies were based in the Reading area of eastern Pennsylvania and manufactured a broad spectrum of aerospace-quality master alloys. KB Alloys also had facilities in Henderson, KY, and Wenatchee, WA. One of the binary master alloys produced by KB Alloys contained 20% nickel and 80% aluminum. Reading Alloys made ferrous and nonferrous master alloys at an 85-hectare (210-acre) site on the outskirts of Robesonia, PA. The company's nickel products included vacuum-grade nickel columbium (niobium) (33% to 38% Ni, 60% to 65% Nb), nickel vanadide (40% Ni, 60% V), and nickel molybdide (50% Ni, 50% Mo).

***Nickel-Based Batteries*.—**U.S. demand for nickel in rechargeable batteries may now exceed U.S. consumption for several other important end uses, such as copper-nickel alloys and coinage. Demand for nickel-cadmium and nickel-metal hydride batteries continued to grow throughout North America and was being spurred by the rapidly expanding U.S. program for recycling household and industrial batteries, which makes the use of nickel-based batteries more environmentally acceptable. Both battery types are widely used in handheld power tools and a myriad of portable electronic devices, including camcorders, cellular telephones, compact disc players, cordless telephones, laptop computers, pocket recorders, and scanner radios. The United States imported \$512 million worth of nickel-cadmium batteries. The bulk of the imported batteries were made, in descending order of market share, in Japan, Mexico, China, Malaysia, or Taiwan.

Although EV's were being commercially manufactured in the EU, Japan, and the United States, production and sales were limited. Honda Motor Co. Ltd. of Japan began leasing its new EV Plus to California fleet owners in May 1997. Nickel-metal hydride batteries power the two-door sedan.

On December 3, General Motors Corporation (GM) introduced its EV1 for the 1999 model year. Customers now had the option of leasing EV1's powered by nickel-metal hydride batteries instead of lead-acid batteries (General Motors Corporation, 1998a, b; Energy Conversion Devices, Inc., 1999). The automobile manufacturer made several major improvements to the EV1 during the preceding 12 months. The 1999 model had a dramatically improved electric drive system. A key part of the drive system—the Generation II Power Electronics Bay—was half the size of its Generation I predecessor and had one-third fewer parts, making it significantly cheaper to produce. The vehicle's inductive charging also was redesigned and simplified. GM's Saturn Division was marketing the two-seater at 33 retail facilities in Arizona and California.

The state-of-the-art nickel-metal hydride batteries enabled the EV1 to travel from 120 to 225 kilometers on a single charge. The batteries were being manufactured by GM Ovonic L.L.C. of Troy, MI, with research support from the U.S. Advanced Battery Consortium. The individual cells were being made at Troy and shipped to Kettering, OH, for final module and battery pack assembly. GM Ovonic was planning to introduce a second generation of nickel-metal hydride batteries in late 1999.

The Generation 1 battery module produced for the EV1 in 1998 weighed 18.2 kilograms and had 11 cells wired in series. Each cell had a nominal voltage of 1.2, giving the module a total voltage of 13.2. The cathode was made from nickel foam and coated with a nickel hydroxide slurry. The anode was an alloy of chromium, nickel, titanium, vanadium, and zirconium. The alloy has a lattice structure that readily accommodates hydrogen ions; that is, protons. The module had a specific energy of 70 watt-hours per kilogram and was able to be fast charged in 35 minutes. GM also began marketing an electric version of its Chevrolet S-10 pickup truck. Like the EV1, the S-10 was powered by nickel-metal hydride batteries (Energy Conversion Devices, Inc., 1997).

Since December 1997, Toyota Motor Corporation of Japan has been selling its new hybrid-powered Prius sedan in Japan and was planning to introduce the vehicle in the United States in late 2000 (Bagot, 1997). More than 20,000 Prius were built during 1998 and the first half of 1999. The vehicle's hybrid power system has an electric motor in addition to the gasoline engine. The Prius has almost twice the fuel efficiency of an equivalent conventional sedan and reportedly gets about 66 miles per gallon. Toyota had three other advanced-technology vehicles under development—a sports utility vehicle powered by nickel-metal hydride batteries, a two-passenger commuter EV powered by nickel-metal hydride batteries, and a fuel-cell-powered EV.

Stocks

The combined stocks of primary nickel maintained in the United States by foreign producers and metal-trading companies with U.S. sales offices increased by 3% during 1998. At yearend, these stocks represented 32 days of apparent primary consumption.

In 1998, LME stocks far exceeded U.S. consumer stocks. In mid-1997, LME stocks began building up again after a drawdown of more than 100,000 tons in 1995-96. By September 1997, LME stocks had climbed back above the 60,000-ton mark. Throughout 1998 and in early 1999, LME stocks remained at the 60,000-ton level. On December 24, 1998, LME warehouses held 65,502 tons of nickel metal, of which 62,610 tons, or 95.6%, was in the form of cut cathodes; the remaining 4.4% consisted of 2,880 tons of briquets and 12 tons of pellets. On December 31, LME stocks totaled 65,964 tons. The 65,964-ton total represented a drop of 56% from the all-time record high of 151,254 tons reached on November 24, 1994. Although the LME now has 25 warehouse sites scattered around the world that are authorized to hold nickel, most of the material continues to be stored at either Rotterdam in the Netherlands or Gothenburg in Sweden; Rotterdam is one of the principal delivery points for Norilsk Nickel.

Prices

Nickel producers had an even more disappointing year in 1998 than they had in 1997. The spot price of nickel metal declined almost continuously throughout 1998. By yearend, the price had dropped to its lowest level for the century in terms of constant dollars. The monthly average cash price for 99.8% pure metal on the LME ended 1997 at a 3-year low of $5,945 per metric ton ($2.697 per pound) and then slipped further during the first quarter of 1998, leveling off briefly at $5,394 ($2.447 per pound) in April. The cash price could not be sustained even at the $5,300 level and entered a period of deterioration lasting more than 6 months. By October, the monthly cash price had dropped to $3,872 per ton ($1.756 per pound)—the lowest point ever recorded by the LME since nickel contracts were introduced in 1979. The price finally stabilized at the very end of 1998 and struggled back above $4,000 in January 1999. Several analysts attributed the 1996-to-1998 price decline to recessionary forces in East Asia and the collapse of nickel consumption in the Russian Federation. Internal demands within Russia for hard currency and the depressed state of the Russian stainless steel industry encouraged Norilsk Nickel to continue exporting the bulk of its production to the West. Increased output from producers in Canada, Cuba, and Finland added to the oversupply situation, further weakening prices. In the end, near-record-high consumption in the West failed to keep up with the supply buildup; Western consumption in 1997 was at an all-time high of 942,000 tons. In 1998, nickel supply in the West exceeded demand by approximately 34,000 tons, or about 4% of consumption.

By December, the monthly LME cash price had fallen to $3,878 per ton ($1.759 per pound) but began to show signs of bottoming out. One of the principal problems was the economic downturn in East Asia which accelerated at the beginning of 1998. The downturn triggered a slump in Japanese stainless steel production and a corresponding drop in Japanese nickel consumption that worsened later in the year. The East Asian economic crisis also affected stainless steel production in the Republic of Korea and Taiwan, further weakening nickel prices.

In 1998, the last weekly price (for the week ending December 25) was $3,822 per ton ($1.734 per pound). The average annual price was $4,630 per ton ($2.100 per pound). The annual price was 33% lower than the 1997 average of $6,927 per ton ($3.142 per pound).

Foreign Trade

U.S. net import reliance as a percentage of apparent consumption was 64% in 1998—14% greater than the percentage for 1997. Imports accounted for 100% of primary supply in 1998, if Government stockpile sales are excluded. Canada, as usual, supplied most of the imported material. The second largest source was Russia, edging out Norway for the second consecutive year. Since 1992, Norilsk Nickel has become an important source of nickel metal for the United States. In 1998, the United States imported 22,300 tons of cathode and 580 tons of powder and/or flake directly from Russia. All the ferronickel produced by Glenbrook in 1998 was derived from New Caledonian ores.

Prices for nickel-bearing scrap tracked those for primary nickel, declining almost continuously from mid-1997 to yearend 1998 because of global oversupply and economic problems in East Asia. Near-record-high exports of Russian scrap added to the downward pressure on primary and secondary prices. Most of the Russian scrap, however, was consumed in the EU and did not enter the U.S. market. The EU imported 324,000 tons (gross weight) of stainless steel scrap from Russia in 1998, down slightly from a record 346,000 tons (revised) in 1997. The EU reported receiving 129,000 tons of scrap from the United States, up from 69,400 tons in 1997 (International Nickel Study Group, 1999c, p. 80-81).

From 1997 to 1999, U.S. exports of stainless steel scrap decreased by 7% despite the small gain in market share in

Europe. The bulk of U.S. scrap went to meltshops in Spain (25% of the total tonnage for 1998), the Republic of Korea (24%), Canada (13%), and Taiwan (9%). The exported scrap contained an estimated 22,374 tons of nickel, down from 27,747 tons in 1997. These last figures are based on the assumption that stainless scrap exports have been averaging 7.5% nickel since 1989.

In mid-1997, four of the larger U.S. producers of specialty steels expressed concern about the country's continuing high level of specialty steel imports and filed a number of antidumping and countervailing duty petitions with the U.S. Department of Commerce and the U.S. International Trade Commission (ITC); the four producers were Allegheny Teledyne, Armco Inc., J&L, and Lukens (Sacco, 1998a). In 1997, specialty steel imports reached a record 797,000 tons. Stainless steel accounted for 624,000 tons, or 78% of the 797,000-ton total. Electrical steel constituted 14%, and tool steel, 8% (Specialty Steel Industry of North America, 1998). According to the Specialty Steel Industry of North America, U.S. imports of stainless steel in calendar year 1997 were 13% greater than those of 1996 (Hartquist, 1998). Imports for 1998 were also higher than 1996 levels and continued to outpace market growth into 1999. The ongoing Asian financial crisis aggravated the situation. Japan, the Republic of Korea, and Taiwan were cited in several of the U.S. producers' petitions. On June 30, 1997, petitions were filed dealing with stainless steel wire rod; on March 27, 1998, with stainless steel wire; on March 31, 1998, with stainless steel plate (in coils); and on June 10, 1998, with stainless steel sheet and strip (in coils). In August 1998, the ITC issued an affirmative decision on imports of stainless steel wire rod, triggering the imposition of antidumping and countervailing duties for that material. The ITC was expected to rule on the remaining cases sometime in the second half of 1999.

World Review

In 1998, the world's largest nickel producer was Norilsk Nickel, followed by Inco, Falconbridge Limited of Canada, and WMC Limited of Australia. A new contender was created in mid-1997 after Billiton Business separated from Gencor and formed Billiton Plc. On September 10, 1997, Billiton transferred its nickel division to QNI in exchange for a 52.4% interest in QNI. Billiton later bought out QNI's minority shareholders and took control of the nickel producer. The merger of Billiton Nickel and QNI brought together several established nickel operations under a single-management structure, thus creating the fifth largest nickel producer in the world. This amalgamation was accomplished in less than 3 years through a series of carefully planned mergers and acquisitions (Billiton Plc., 1997a, p. 45-58; 1997b, p. 1-47; Platt's Metals Week, 1997a).

In October 1998, Anglo American Plc merged with Minorco S.A. of Luxembourg, its sister company (Gleason, 1998; Schuettler, 1998). The combined companies had assets of more than $10 billion (Cant, 1998). In conjunction with the merger, Anglo moved its headquarters from South Africa to the United Kingdom, and became a United Kingdom registered company with a primary listing on the London Stock Exchange. The new company remained committed to its South African origins despite the move to London (Schuettler, 1999). The ongoing restructuring of Anglo eliminated a number of cross-holdings (Cant, 1998). Anglo has become increasingly involved in several nickel projects since 1995 and was constructing a laterite mining and smelting complex in Venezuela at Loma de Niquel, southwest of Caracas.

Australia.—The Australian nickel industry was in the midst of a major expansion. Three laterite projects were commissioned in late 1998. Some $3 billion has been committed to projects that will increase Australia's mine production capacity by more than 77,000 tons per year of nickel. Total mine production reached 144,000 tons of nickel in concentrate and was projected to increase to more than 200,000 tons in 2001.

Australian Sulfide Operations.—In late 1998, WMC began cutting back on production at its operations in Western Australia because of weak nickel prices. On September 15, the company announced that it would reduce production of nickel concentrate at its Kambalda operations by 10,000 tons per year of contained nickel. Mining was to be suspended at three of Kambalda's seven mining complexes—Blair, Otter/Juan, and Wannaway; the three were reportedly the higher cost operations in the group (WMC Limited, 1998).

Despite the cutbacks, WMC produced 119,700 tons of nickel in concentrate in 1998—breaking all previous records for the seventh consecutive year (WMC Limited, 1999a, p. 52). The Mount Keith Mine northwest of Leinster was in its fourth year of operation and accounted for 42,000 tons, or 35% of the total output, making it one of the larger metal mines in Australia. The ore has been grading 0.60% nickel. The concentrate was being dried at Leinster and then shipped either to WMC's smelter at Kalgoorlie or to Outokumpu Oyj's refining and smelting complex at Harjavalta, Finland. WMC's other two mining operations—Kambalda and Leinster—produced 33,400 and 44,300 tons of nickel in concentrate, respectively. The recently expanded smelter at Kalgoorlie can now process concentrate at a much greater rate than in the past (WMC Limited, 1999b, p. 22 and SR 8-17). The smelter produced 100,100 tons of nickel in matte, far surpassing the 85,800 tons reported for 1997. The large increase in production was due, in part, to the smelter's new sulfuric acid recovery plant. The acid plant was commissioned in July 1996 and has reduced sulfur dioxide emissions by more than 80%. WMC's nickel refinery at Kwinana produced a record 53,700 tons of metal, up 14% from that of 1997.

The Forrestania Mine near Varley, Western Australia, produced 9,200 tons of nickel in concentrates in calendar year 1998, up from 7,900 tons in 1997. The mining operation excavated 400,000 tons of ore averaging about 2% nickel. The open pit mine had only 200,000 tons of proven reserves grading 2.5% nickel and an additional 100,000 tons of probable reserves grading 2.1% nickel (Outokumpu Oyj, 1999, p. 64). Company geologists estimate about 2.7 million tons of indicated resources, also averaging 2.1% nickel, is in the immediate vicinity of the mine. At the present rate of mining, Forrestania's reserves could be exhausted before 2001. Forrestania has been in operation since November 1992 and is owned by Outokumpu Mining Australia Pty. Ltd., a wholly owned subsidiary of Outokumpu Base Metals Oy and its Finnish-based parent, Outokumpu Oyj.

At the beginning of 1998, Outokumpu Mining Australia had three other projects under development in Western Australia—Black Swan, Cygnet, and Silver Swan. All had been 50-50 joint ventures with Mining Project Investors Pty. Ltd. (MPI) of Australia. During the year, however, Outokumpu Base Metals became sole owner of the three small, high-grade ore bodies and consolidated development (Outokumpu Oyj, 1998c). The three ore bodies now form the Black Swan Mine and are owned by Outokumpu Exploration Ventures Pty. Ltd. The properties are along the Yarri Road 53 kilometers northeast of Kalgoorlie. Outokumpu Base Metals sold its 34% interest in MPI as part of the transaction. The 34% interest in MPI had effectively given Outokumpu a 67% equity in each of the three former projects.

Production at the Silver Swan Mine began on June 1, 1997, and was scheduled to continue for at least 5 years at a rate of 12,000 tons per year of nickel in concentrate. The concentrate was being loaded onto ocean-going vessels at the port of Esperance and shipped to the Harjavalta smelter for further processing. The new underground mine had about 80 employees. Outokumpu geologists estimated that the Silver Swan has 400,000 tons of proven and probable ore reserves with an exceptionally high grade of 9.4% nickel. The adjacent disseminated Cygnet deposit is roughly the same size as the Silver Swan and reportedly has 1.1 million tons of probable reserves grading 2.1% nickel. The Black Swan ore body reportedly has 30 million tons of inferred resources at 0.8% nickel (Outokumpu Oyj, 1999, p. 64).

On October 21, 1997, Outokumpu Base Metals became the sole owner of the Honeymoon Well project, also in Western Australia, buying out its partner, Rio Tinto Exploration Pty. Limited. The Honeymoon Well deposit is in the Shire of Wiluna about 60 kilometers northwest of the giant Mount Keith Mine owned by WMC. According to Outokumpu, the Honeymoon Well deposit has 118 million tons of indicated resources, averaging 0.8% nickel at a cutoff grade of 0.5% nickel. An additional 10 million tons of resources, averaging 0.7% nickel, are inferred. The nickel is in the form of disseminated sulfides and would be recovered by using bulk mining techniques similar to those employed at the Mount Keith Mine.

In 1996-97, exploration crews employed by Jubilee Gold Mines NL identified several geophysical and geochemical anomalies associated with two belts of ultramafic rocks in the Kathleen Valley, southeast of the Mount Keith Mine and about 40 kilometers north of Leinster. Subsequent drilling of the anomalies resulted in the discovery of the Cosmos ore shoot. Of the six holes drilled to date, four have intersected massive sulfide near the base of one of the ultramafic units. The best intercept was 22.3 meters grading 9.29% nickel starting at a depth of 122 meters in drill hole JCD002 (Jubilee Gold Mines NL, Cosmos Nickel, accessed December 8, 1999, at URL http://www.jubileegold.com.au/projects/projects_cosmos.html). Jubilee was in the process of finalizing its minerals lease and resolving Native Title claims (Hookham, 1998b).

Australian Laterite Operations.—Western Australia was rapidly becoming a major processor of laterite ores, rivaling Cuba and New Caledonia. The pressure acid leach (PAL) process is now being used to recover nickel from lateritic ores at three recently commissioned operations in the Kambalda-Goldfields region. PAL technology was pioneered at Moa in Cuba during the late 1950's, but the technology was not commercially adapted to Australian laterites until 1997. Three nickel laterite mining and processing operations have been commissioned in Western Australia since mid-1998—Bulong, Cawse, and Murrin Murrin. Development was spurred by the construction of the Goldfields natural gas pipeline from the Pilbara coast to Kalgoorlie. The three nickel laterite projects continued to move forward with plans to dramatically expand existing capacity despite the lowest nickel prices in more than a decade (Treadgold, 1998).

On November 5, 1998, Resolute Limited sold the Bulong project to Preston Resources Limited of Perth. In return, Resolute received A$280 million in cash and common stock in Preston valued at A$39.9 million. The new stock issue increased Resolute's equity in Preston to 19.9% (Platt's Metals Week, 1998d; Resolute Limited, 1998).

The Bulong project has been under development for more than 10 years. Stage I was essentially complete (Hookham, 1998a). The nickel and cobalt were being recovered by using solvent extraction-electrowinning technology (Mining Journal, 1999). Engineering and technical support was being provided by the BKK Consortium (Bateman Limited, the Kinhill Group, and the Kilborn Group). The Bulong operation was to produce nickel cathode and cobalt cathode. The Bulong process has seven stages. In the first stage, the clay-rich ore is washed, ground in ball mills, and made into a slurry. The slurry is then pumped into an autoclave where acid and steam are injected. The slurry is acid pressure leached in the autoclave at 250° C for about 75 minutes. The leached solution is progressively cooled in a series of flash tanks and passed through a counter-current decantation thickener circuit to make a pregnant liquor. After neutralization with limestone, the liquor is clarified and eventually sent to a solvent extraction circuit where the cobalt is separated from the nickel and precipitated as cobalt sulfide. The nickel-bearing raffinate is pumped to a second solvent extraction circuit where the nickel is recovered and converted into an electrolyte. In the final stage, the nickel electrolyte is pumped into the electrowinning circuit, causing LME-grade nickel metal to be deposited on the cathode. According to Resolute, Bulong had 41 million tons of reserves, averaging 1.14% nickel and 0.09% cobalt plus 140 million tons of additional resources of similar grade (Resolute Limited, Bulong nickel project, accessed December 4, 1998, at URL http://resolute-ltd.com.au/sc06-bulong/html).

Commissioning of the Cawse hydrometallurgical plant began on September 9, 1998, but stripping and mining had been underway at two open pits since April. By late 1998, Centaur Mining & Exploration Ltd., the mine owner, had spent A$234 million on the project. The hydrometallurgical plant was scheduled to begin producing cathode in late December or early January but experienced technical problems that delayed commissioning (Metal Bulletin, 1998a; Platt's Metals Week, 1998a). Output for the first full year of production should be about 8,400 tons of nickel plus 2,000 tons of cobalt in sulfides. Like Bulong, the Cawse project uses pressure acid leaching and electrowinning to recover the nickel. The Cawse Mine is 50 kilometers northwest of Kalgoorlie. The mine reportedly has 30 million tons of reserves averaging 1% nickel and 0.06% cobalt plus 213 million tons of resources estimated to grade 0.7% nickel and 0.04% cobalt. S.A. Sogem N.V. of Belgium was to market Centaur's production (Minerals Gazette, 1998).

Murrin Murrin, the largest of the three laterite projects, was more than 95% complete at yearend 1998. The project was a joint venture of Anaconda Nickel Limited (60% equity) and Glencore International AG of Switzerland (40%); Anglo and Sherritt later became partners. Almost A$950 million had been invested in the project by yearend 1998. Metal production was scheduled to begin in mid-December and, by 2003, could reach 45,000 tons per year of nickel and 3,000 tons per year of cobalt. More than 2,000 construction workers and permanent employees were at the site east of Leonora.

At Murrin Murrin, a pressure-sulfuric acid leach technology licensed from Sherritt was being used to recover the nickel. In September 1998, the first shipment of elemental sulfur—some 45,000 tons—was unloaded at Kwinana, a port and industrial suburb of Perth, for delivery by rail to Murrin Murrin (Anaconda Nickel Limited, 1998). The sulfur, supplied by Shell Canada Limited, was being converted to sulfuric acid at the mine site. The feasibility study for Murrin Murrin Stage II was also almost finished. Stage II construction would increase total annual production capacity to 115,000 tons of nickel and 9,000 tons of cobalt. The mine reportedly had 132 million tons of reserves averaging 0.94% nickel and 0.06% cobalt. Additional resources totaling 221 million tons of material were estimated to average 0.88% nickel and 0.06% cobalt.

Anaconda also was preparing to develop its Mount Margaret property, 100 kilometers northwest of Murrin Murrin. Preliminary testwork reportedly indicated a resource of at least 170 million tons grading 0.78% nickel and 0.045% cobalt (Anaconda Nickel Limited, 1999). Potential resources in the Mount Margaret region, however, reportedly exceed 500 million tons. Drilling was underway to delineate better the resources at Mount Margaret.

In 1998, Preston completed a feasibility study on its wholly owned Marlborough project. Since then, the company has met several permitting requirements and resolved outstanding Native Title issues. The environmental impact assessment also has been completed. The project is in central Queensland about 75 kilometers northwest of Rockhampton. Production was scheduled to begin in 2001. Preston commissioned Multiplex Constructions Pty. Ltd. and Kvaerner Metals ASA to expand and update feasibility estimates made by the BKK Consortium, the previous evaluator. Considerable metallurgical testing and several environmental studies have been carried out since the BKK evaluation. Preston also revised its mine plans and resource estimates. Under the revised mining plan, the Marlborough operation would produce 25,000 tons per year of nickel metal and 2,000 tons per year of cobalt metal. Total capital costs were estimated to be A$688 million (Preston Resources Limited, 1999).

Preston was planning to mine some 3.7 million tons per year of ore from a cluster of open pits on the Marlborough property and truck the material to a central processing plant. The proposed hydrometallurgical plant would cost A$578 million. Resources reportedly are sufficient to permit the plant to operate for at least 22 years and possibly as long as 100 years. According to company officials, Marlborough has some 210 million tons of resources grading 1.02% nickel and 0.06% cobalt (Preston Resources Limited, 1999). The minable reserve was reported to be 52 million tons averaging 0.88% nickel and 0.06% cobalt. Preparatory beneficiation would raise the grade of the ore to 1.50% nickel and 0.13% cobalt. The beneficiated ore would be fed into an autoclave and acid leached under pressure. After autoclaving, the nickel would be recovered by ammonia re-leaching and solvent extraction, and then refined by electrowinning. Hydrometallurgical recovery of the nickel was expected to be about 92%. Marlborough's metallurgical process design was being strongly influenced by Preston's experiences with its Bulong operation. Part of Marlborough's power requirements would be derived from an onsite sulfuric acid plant. Power would be generated by using excess steam produced during the conversion of elemental sulfur to sulfuric acid.

Processing of Intermediates and Refining.—QNI produced 26,855 tons of nickel metal at its Yabulu refinery in Queensland during fiscal year 1997-98 (QNI Limited, 1999, p. 32-33). Laterite feed for the refinery was being supplied by PT Aneka Tambang in Indonesia, Hinatuan Mining Corp. in the Philippines, and four mining companies in New Caledonia. Calliope Metals Corporation continued with its plans to build a A$465 million nickel and cobalt processing plant at Gladstone. The 20,000-ton-per-year nickel operation would rely on laterite ore from New Caledonia.

Canada.—Key events of 1998 are summarized in the nickel chapter of the Canadian Minerals Yearbook (McCutcheon, 1999).

Labrador.—Inco and Voisey's Bay Nickel Company Limited, its subsidiary, remained committed to developing the huge nickel-copper-cobalt deposit near Voisey's Bay in northeastern Labrador. An impasse between Inco and the Provincial Government of Newfoundland and Labrador over the scope of the project has temporarily delayed development (Inco Limited, 1999a, p. 20-21; 1999b; 1999c, p. 6-8). The Voisey's Bay complex was the first major mining and milling project to be subjected to a full review under Canada's new Environmental Assessment Act. Inco submitted its environmental impact statement to Canadian Federal and Provincial authorities in December 1997 and spent the next 12 months negotiating impact and benefit agreements with the local Labrador Innu and Innuit communities.

Weak nickel prices in 1998 forced Inco to reassess its original plans to build a smelter and refinery at Argentia on Newfoundland. The Argentia complex was to have processed pentlandite concentrate shipped by sea from the proposed mill near Voisey's Bay. Inco also was reluctant to proceed with critical parts of the project until representatives of the First Peoples Nations (the aboriginal peoples in the region) concluded their land claim negotiations with the Federal and Provincial Governments. The two principal aboriginal groups involved were the Labrador Inuit Association and the Innu Nation, both of which were separately negotiating impact and benefit agreements with Inco. In December 1998, the Labrador Inuit Association reached a tentative agreement-in-principle with the Federal and Provincial Governments on land claims issues (Government of Canada, 1999).

In January 1997, a five-member panel was created to oversee the environmental review process for the proposed mine and mill. The panel was established by a memorandum of understanding signed by the Governments and the two aboriginal groups. In December 1997, Inco submitted an in-depth and lengthy EIS on the mining and milling portion of the project to the assessment panel and regulatory authorities (Inco Limited, 1997a; Voisey's Bay Nickel Company Limited, 1997). After an extensive review, the panel held public hearings from September to early November 1998 at various locations in the Province. On April 1, 1999, the panel recommended that Inco be given tentative approval to proceed with the project, subject to a number of stipulations. The panel made more than 100 recommendations as part of its report (Inco Limited, 1999b).

In August 1997, the Newfoundland Court of Appeal granted a temporary injunction, preventing the construction of a temporary road and airstrip at Voisey's Bay. The absence of the airstrip kept Inco from conducting underground exploration and developing an underground mining plan. The ruling was appealed to the Supreme Court of Newfoundland. Because of the ruling, exploration teams have had to rely on surface drilling to gather information about the geology of the area. A new zone of mineralization was identified 400 meters north of the Eastern Deeps section. Two holes drilled at opposite ends of the North of Eastern Deeps zone intersected mineralization. The first hole reportedly intercepted 25.2 meters of sulfides grading 0.96% nickel, 0.82% copper, and 0.056% cobalt. The second hole intercepted 15 meters of sulfides grading 1.11% nickel, 0.93% copper, and 0.074% cobalt. Inco geologists continued to evaluate the Kiglapaits property 60 kilometers north of the main claim area. The results to date have been very promising. In fall 1998, drilling intersected narrow bands of nickel mineralization.

Donner Minerals Limited and its partners continued to explore their claims in the South Voisey's Bay (SVB) project area. Between May and December 1998, the venture partners drilled 39 new holes and deepened 5 others for a total of 15,218 meters (Donner Minerals Limited, 1998a, b). In October 1998, Teck Corp., a Canadian nonferrous metals producer and SVB project sponsor, agreed to invest an additional C$1.05 million in Donner. Donner and its partners had planned to spend C$2.75 million during the 1999 field season. The exploration program was to have included airborne and ground geophysical work, as well as diamond drilling (Donner Minerals Limited, 1999a). Donner, however, announced that the company has been unable to reach an agreement with the Innu Nation. Donner was unwilling to risk a confrontation at its SVB exploration camp and decided to cancel its 1999 exploration program (Donner Minerals Limited, 1999b).

Manitoba.—In 1996-97, the Geological Survey of Canada published new aeromagnetic maps indicating that a magnetic lineament at the northern end of the Thompson Nickel Belt of Manitoba may continue northeast toward Cape Churchill. At least 18 significant nickel deposits already have been discovered along the Thompson Nickel Belt, which extends from Willam Lake more than 200 kilometers northeast to Moak. Some geologists have suggested that this newly identified lineament could connect with the Ungava Nickel Belt on the eastern side of Hudson Bay. Both the Thompson and the Ungava Nickel Belts are located at the boundary of the Churchill and Superior Geologic Provinces and have a number of geologic similarities (Canmine Resources Corp., 1999). To test this theory, Canmine Resources Corp. acquired more than 2,000 square kilometers of claims northeast and west of the Thompson Nickel Belt and began drilling some of the more promising geophysical anomalies along the lineament.

Canmine had a second project underway in Manitoba. In 1996, the company acquired the Maskwa property 120 kilometers northeast of Winnipeg. In May 1998, Canmine filed an initial proposal with Environment Manitoba to construct a C$20 million mine at Maskwa. According to company officials, the main deposit at Maskwa has 2.93 million tons of indicated resources grading 1.27% nickel, 0.21% copper, and 0.04% cobalt.

Quebec.—Significant development work and exploration activity continued in northern Quebec. On December 10, 1997, Falconbridge began producing nickel-copper-cobalt concentrates at its new Raglan Mine. Startup was 3 months earlier than originally planned. By early 1998, Falconbridge had spent more than C$500 million on development and construction. In April 1998, the mining and milling complex reached commercial production (Falconbridge Limited, 1997, 1998c).

The new nickel-copper mine is near Katinniq, at the tip of the Ungava Peninsula in the Nunavik region of northern Quebec. Raglan has an annual rated capacity of 21,000 tons of nickel in concentrate but reportedly can be expanded to 30,000 tons per year if market conditions warrant (Falconbridge Limited, 1999, p. 8-19). Raglan was fully operational by mid-1998 and increased the company's production of nickel in sulfide concentrates by almost 50%. Ore was coming from several open pits and an underground mine at Katinniq. In 1998, Raglan recovered 636,000 tons of ore averaging 3.14% nickel and 0.96% copper. This included preproduction material and equated to a mine production figure of 16,400 tons of nickel in concentrate.

During the year, Falconbridge discovered a new deposit at East Lake 13.5 kilometers west of the Katinniq concentrator. According to company officials, a minimum of 1.15 million tons of indicated resources have been delineated at East Lake. The newly discovered resources grade 3.71% nickel, 1.09% copper, and 0.08% cobalt (Falconbridge Limited, 1999, p. 27). At yearend 1998, Raglan reportedly had 19.4 million tons of proven and probable reserves averaging 2.85% nickel and 0.77% copper. In addition to the reserves, Raglan reportedly had 5.25 million tons of indicated and inferred resources averaging 2.27% nickel and 0.82% copper. All the ores occur in the northeastern part of the Cape Smith Fold Belt, which extends across the entire width of the Ungava Peninsula.

On January 20, 1999, Nuinsco Resources Ltd. of Toronto reported that a drill hole on its nickel-copper prospect near Lac Rocher had intersected disseminated and massive sulfides over a length of some 80 meters (Skillings Mining Review, 1999; Whyte, 1999). The Nuinsco property is in the Lac Evans region about 120 kilometers northeast of Matagami, Quebec. The Matagami mining camp is in the northern part of the

Abitibi Subprovince, one of the largest Archean greenstone belts in the world (Adam, Milkereit, and Mareschal, 1998). Noranda Inc. has been mining volcanogenic massive sulfide deposits in the Matagami district for copper, gold, silver, and zinc for more than two decades.

Cuba.—At least two other prominent nickel producers besides KWG Resources Inc. and Sherritt have entered into agreements with Cuban parastatal organizations since 1993. Gencor had been evaluating a lateritic deposit in the San Felipe area of Camaguey Province. Gencor's interests in the deposit were transferred to the new QNI organization in late 1997 when QNI merged with Billiton Nickel. In February 1998, QNI negotiated a new agreement with Cuban authorities. QNI would have a 75% interest in the joint venture—San Felipe Mining BVI Limited, a subsidiary of Gatro Caribbean Investments Limited; GeoMinera S.A., a mining investment company of the Cuban Government, would hold the remaining 25%. In exchange, QNI would spend a minimum of $350,000 on fieldwork and complete other undisclosed exploration and evaluation tasks (QNI Limited and Billiton Plc, 1997, p. 29; QNI Limited, 1999, p. 26). Exploration crews reportedly identified more than 150 million tons of laterite resources grading about 1.4% nickel during the first phase of the San Felipe drilling program and earlier studies (Billiton, 1997b, Book 2, p. 44). The resource zone is about 10 meters thick.

In September 1994, Western Mining Corporation Holdings Limited of Australia (now WMC) signed an MOU with Commercial Caribbean Nickel S.A. to evaluate and develop the Pinares de Mayari West lateritic deposit in Holguín Province. Negotiations continued for another 3 years. In February 1998, WMC and the State-owned enterprise finalized their agreement. Cuban authorities issued the last of the licenses permitting test drilling to resume in the second quarter of 1998. All the initial mining, metallurgical, environmental, and cost studies were scheduled to be completed by July 1999. The Pinares deposit reportedly contains more than 200 million tons of ore exceeding 1% nickel and 0.1% cobalt (WMC Limited, 1999a, p. 29). WMC was planning to use high-pressure leaching technology developed by Sherritt to recover the nickel and cobalt (Metal Bulletin, 1996). The overall hydrometallurgical process would be similar to the ones employed at Moa and in Western Australia.

Dominican Republic.—Falconbridge Dominicana, C. por A. (Falcondo) produced 25,209 tons of nickel in ferronickel, down from the record of 32,545 tons set in 1997. The ferronickel typically contains 38% nickel and is cast into gumdrop-shaped ferrocones, a form that makes bulk transportation and handling easier for the customer. On December 31, 1998, Falcondo reportedly had proven, probable, and possible ore reserves totaling 78.5 million tons and averaging about 1.17% nickel (Falconbridge Limited, 1999, p. 14). During the past few years, the grade of the laterite mined at Bonao has gradually declined, requiring more ore to be fed to the furnaces. To counter the dropoff in nickel content, Falcondo was developing an improved circuit for upgrading the laterite prior to reduction in the electric arc furnace.

On October 25, 1998, Falcondo temporarily suspended production at its Bonao mining and smelting complex because of low prices for nickel. The shutdown of the ferronickel smelter lasted for more than 3 months (Falconbridge Limited, 1998a, 1999, p. 22). During the 3 months, maintenance crews overhauled one of the smelter's two 55.5-megawatt electric furnaces, as well as the complex's 200-megawatt powerplant. A third electric furnace had been idle for some time. Falcondo used vertical shaft furnaces instead of rotary kilns to calcine and prereduce the laterite ore. The hot prereduced calcine is transferred to one of the electric furnaces and melted, forming ferronickel that is then separated from the slag. The repairs and overhauling should improve efficiency of the overall operation and reduce production costs. In 1995, Falcondo stopped producing ferronickel ingot and now makes only ferrocones containing 40% nickel and 60% iron. In 1997, the smelter operated at full capacity.

On September 22, Hurricane Georges damaged some of the buildings in the Bonao complex. Both electric furnaces were shut down as a precautionary measure before the hurricane struck the island (Falconbridge Limited, 1998e). The hurricane cost Falcondo 10 days of production (Falconbridge Limited, 1998f). Because of the 3-month shutdown and the interruption caused by Hurricane Georges, production for 1998 was much lower than originally projected (Falconbridge Limited, 1999).

New Caledonia.—Société Métallurgique Le Nickel (SLN) operated four nickel mines on the island in 1998—Thio, Kouaoua, Népoui-Kopéto, and Tiébaghi. A fifth mine, Kaala-Gomen (also known as Etoile du Nord), was being operated by contractors. Tiébaghi, a new mining operation, began delivering ore to the Doniambo smelter in September 1998. Despite heavy rains, SLN's total ore production was greater than that of 1997. SLN and its subcontractors mined 3.30 million tons of wet lateritic ore, up from 2.94 million tons in 1997. Mines operated directly by SLN accounted for 2.58 million tons, or 78% of the 3.30 million tons (Eramet Group, 1999, p. 17-22 and 84a). The Paris-based Eramet Group controlled 90% of the shares of SLN.

At Doniambo, the ores from the five mines were blended along with ores from a few independently operated mines, partially dried, calcined, and then smelted in one of three electric arc furnaces. The Doniambo smelter produced ferronickel granules containing 29% nickel and nickel matte that assayed about 75% nickel. The matte was sent to the Sandouville-Le Havre refinery in northern France for conversion into cathode. In 1998, the Doniambo smelter produced 44,491 tons of nickel in ferronickel and 12,011 tons of nickel in matte. The combined output of 56,502 tons was an all-time high for Doniambo, breaking the previous record of 54,892 tons set in 1997. A fifth rotary kiln was commissioned in late 1998, raising the annual capacity of the plant to 63,000 tons of contained nickel.

SLN accounted for 47% of New Caledonian mine production in 1998. The other 53% of mine production was divided among SMSP, J.C. Berton Mines, Nickel Mining Corp., Société des Mines de la Tontouta, and several other independent mining companies. In 1998, the overseas territory exported 59,938 tons of nickel in ore, which included 38,772 tons of nickel in garnierite shipped to Japan, 19,742 tons in limonitic laterites shipped to Australia, and 1,424 tons in garnierite shipped to the United States.

In 1996, SMSP and Falconbridge formed a partnership with the intention of building a ferronickel plant in the North Province. The plant would have an annual capacity of 54,000 tons of nickel in ferronickel and use local lateritic ores as feedstock. The project has since moved much closer to reality (Falconbridge Limited, 1999, p. 28). To make the project viable, the two partners had to convince SLN to exchange mining reserves with SMSP at two different locations on the island. On February 1, 1998, after lengthy negotiations, SMSP signed a protocol with the French Government, Eramet, and others, thus permitting the exchange of the critical mining assets. Under the protocol (also called the Bercy Agreements), SMSP gained access to SLN's deposits in the Koniambo massif. In exchange, SLN received mining rights to smaller and poorer deposits in the Poum massif held by SMSP (Falconbridge Limited, 1998b). Construction of the smelter must begin by January 2006 or the Koniambo deposit reverts to SLN (Eramet Group, 1999, p. 57). SAS Poum-Koniambo, an interim company, was set up to carry out the mechanics of exchanging the mining properties. The interim company was controlled by the French Government (with a 99% equity) and managed by three international investment banks.

The French Government paid Eramet FRF1 billion (US$167 million) as compensation for swapping Koniambo for Poum and the resulting loss of ore reserves due to the exchange (Gooding, 1998; Eramet Group, 1997, p. 17; 1999, p. 57). Prefeasibility studies of the Koniambo deposits began in mid-1998. The agreement between the French Government and Eramet cleared the way for SMSP and Falconbridge to start the feasibility study of the North Province smelter; this study is expected to cost FRF38.5 million (US$6.4 million). The agreement also permitted resumption of political negotiations between the French Government and Front National de Liberation Kanak et Socialiste—the island's separatist party and a strong supporter of the SMSP-Falconbridge project. The party leadership was hoping that the North Province smelter would add value to the island's nickel exports and improve employment opportunities for the islanders (Mining Journal, 1997).

Falconbridge and SMSP formalized their own mining and smelting agreement on April 29—87 days after the signing of the protocol (Falconbridge Limited, 1998b). Société de Financement et d'Investissement de la Province Nord, the controlling shareholder in SMSP, also signed the joint-venture agreement. The proposed smelter was expected to cost more than FRF6 billion (or about US$1 billion). SMSP was to have a 51% interest in the project, and Falconbridge, 49%.

In September 1997, Inco's management gave the go-ahead to construct a US$50 million pilot plant near the Goro laterite deposits at the southeastern tip of Grande Terre, the main island. The main Goro deposit has 165 million tons of lateritic resources averaging 1.60% nickel and 0.16% cobalt (Inco Limited, 1997c; 1998a, p. 32). Drilling has already outlined 47 million tons of proven and probable reserves—enough to supply a commercial-sized plant for 20 years. The project was a joint venture of Inco (85%) and Bureau de Recherches Géologiques et Minières, the French Government agency (15%).

The fully integrated pilot plant was constructed from modules built in Canada and assembled on-site. The pilot plant was completed in 1999 and will be able to process 12 tons per day of ore by using proprietary technologies developed in-house by Inco. The pilot plant also would provide the residue needed to help design a tailings containment facility. The hydrometallurgical extraction process involves pressure acid leaching and solvent extraction. Inco's autoclaves have been designed to operate at a higher temperature than those in Western Australia. About 70 people work at the plant.

Inco was considering building a full-scale commercial plant on-site if the pilot plant proves to be a success. The proposed commercial plant would be built in two stages and have initial annual capacities of 27,000 tons of nickel and 2,700 tons of cobalt (Inco Limited, 1998b, p. 27; 1999a, p. 19-20). The plant would be designed so that its production capacity could be readily doubled to 54,000 tons per year of nickel. The nickel would be in the form of oxide, not electronickel or hydrogen-reduced nickel metal. The capital cost of the commercial plant would be about $1.4 billion.

Russia.—The Russian Federation produced 227,000 tons of nickel in refined products, down slightly from 230,000 tons in 1997 (International Nickel Study Group, 1999a, 1999c, p. 58-61). Norilsk Nickel was by far the largest producer in Russia, accounting for 217,000 tons of nickel in metal or limited amounts of ferronickel, as well as 389,000 tons of copper metal, and 4,630 tons of cobalt in metal, oxide, or sulfate. Norilsk Nickel produced 22% more nickel in 1998 than in 1996, when the company had a reported output of 177,185 tons (Platt's Metals Week, 1998b, c; Interfax International Limited, 1999a, c; RAO Norilsk Nickel, 1999a). In December 1997, an amendment was made to Russia's law on state security that prohibits Norilsk Nickel from releasing detailed production figures for its different subsidiaries (Metal Bulletin, 1998b). Part of the 1996-98 production increase was attributed to improved flotation separation techniques at the company's largest operation, the Norilsk Nickel Mining and Metallurgical Combine on the Taimyr Peninsula. The introduction of two new flotation reagents (reportedly DMDK and DP-4) had dramatically increased concentrate recovery. Norilsk Nickel has been keen to introduce new technology and to renovate existing production processes. A 3.3% increase in nickel output from 1997 to 1998 at the Norilsk Combine offset a nongrowth situation at the company's smaller Severonickel Combine at Monchegorsk on the Kola Peninsula (Interfax International Limited, 1999b). The bulk of Norilsk Nickel's production was being exported. Less than 20,000 tons, or 9% of the company's 1998 output, went to Russian consumers. Russian consumption of primary nickel was at its lowest level since the dissolution of the Former Soviet Union in December 1991 and, possibly, since the beginning of World War II.

Norilsk Nickel continued to restructure all its mining and processing operations as part of its 4-year-old privatization program. To improve management of the company, the Kola Mining and Metallurgical Company and the Norilsk Mining Company were created during 1998. Their purpose was to make Norilsk Nickel more competitive in the international marketplace and more attractive to foreign investment. Modernization of operations on the Taimyr Peninsula had first priority because the Taimyr ores are much richer than those mined by the Pechenganickel Combine on the Finnish border.

The Taimyr ores typically grade 1.5 to 3.2% nickel compared with 0.6 to 1.7% nickel for Pechenga. To reduce operational costs, Norilsk Nickel halted its long-time practice of shipping part of the ore mined on the Taimyr Peninsula to the Severonickel smelter at Monchegorsk. Shipping ore by ocean vessel from Norilsk's docks at Dudinka across the Barents and Kara Seas to Murmansk was no longer cost effective. The cutback in matte production at Monchegorsk was largely offset by improved production efficiencies and higher recovery rates at the company's concentrators and smelters on the Taimyr Peninsula. The Severonickel Combine now primarily processed either nickel-copper matte from Norilsk and Pechenga or recycled materials. The recycled materials were being smelted in electric or autogenous furnaces and then converted to matte. The nickel was separated from the copper in converters, cast into anodes, and then refined by electrolysis. Outokumpu was helping Norilsk Nickel evaluate, upgrade, and modernize all three complexes.

During the year, Norilsk Nickel transferred its holdings in AO Krastsvetmet to the Krasnoyarsk regional property fund. The transfer settled tax obligations and other outstanding debts owed to regional authorities (RAO Norilsk Nickel, 1999a). Krastsvetmets principal assets were a precious metals refinery and jewelry factory in Krasnoyarsk. The refinery continued to be an important supplier of palladium, platinum, and rhodium, as well as gold and silver. Many of the refinery's feed materials were byproducts of the Norilsk Combine's nickel operations.

Development of the Pelyatkinskoye natural gas field began in north-central Siberia. The consortium responsible for development was spending $360 million to construct a transmission pipeline from the gasfield to the smelting and refining complex at Norilsk. The pipeline could be in operation as early as 2001 and should reduce the possibility of future fuel shortages (RAO Norilsk Nickel, 1999b). In 1996, the Norilsk Combine had difficulty maintaining production because of cutbacks in deliveries of natural gas from its sole supplier NorilskGazProm. NorilskGazProm had threatened to reduce deliveries by 25% if Norilsk did not pay $173 million owed the utility.

In December 1997, Outokumpu formed a joint venture with Norilsk Nickel to evaluate a number of mines and resources controlled by Norilsk on the Kola Peninsula. A/O Polar Mining, the new venture, was conducting an 18-month study to determine if it would be profitable for Norilsk and Outokumpu to upgrade some of Norilsk's existing mining and concentrating operations in the Pechenga area. A/O Polar Mining also was exploring the possibility of developing new mines in the Monchegorsk and the Pechenga regions. The feasibility study focused on ways of lowering mining and mineral dressing costs while meeting the most stringent environmental standards accepted by the international community. Alternative sources of financing were also to be investigated.

Russia had three smaller producers, all in the Ural Mountains—RAO Režsky Nickel, RAO Ufaley Nickel, and RAO Yuzural Nickel (International Nickel Study Group, 1999a). The Ural producers continued to be hampered by escalating prices for energy, especially coal, and a shortage of capital for modernization.

According to statistics compiled by the central government, Russia exported 212,186 tons of unwrought nickel (Harmonized Tariff Schedule No. 7502.10) in 1998. Of the 212,186 tons, 196,903 tons, or about 93%, went into LME warehouses in Rotterdam. The only other significant direct destinations were Finland and Germany, which accounted for 6,685 tons (3.2%) and 6,066 tons (2.9%), respectively. In the past few years, Russia has become an important source of nickel-bearing stainless steel scrap. In 1998, approximately 326,000 tons of stainless scrap (on a gross weight basis) entered the EU (International Nickel Study Group, 1999c, p. 80-81 and 86).

Current Research and Technology

Electroless Nickel Plating.—Demand for electroless nickel plated parts has resumed its upward growth after a hiatus of some 10 years (Duncan, 1995). The annual growth rate since 1995 has been estimated to be about 5%. A large part of this new growth has been attributed to rising production of personal computers and their hard-disk drives, in particular. Some of the latest disk drives have a spindle holding as many as eight magnetically coated platters. The number of platters, which spin at several thousand rotations per minute, and the composition of the magnetic material coating each platter determine the capacity of the drive. The individual platters are coated with an alloy about 0.08 micrometers thick.

Other leading applications included electronics coatings and automotive and machinery parts. The most common use of electroless nickel is for corrosion protection. Another important use is for a hard finish or wear resistance. Lesser uses include adhesion enhancement, bondability, conductivity, lubricity, magnetic response, and uniformity.

Electroless nickel solutions have a variety of chemical components. Nickel is generally added as nickel sulfate. Sodium hypophosphite ($NaH_2PO_2 \bullet xH_2O$) is frequently used as the reducing agent. Chelators, usually organic acids, help keep the dissolved nickel in solution and regulate the amount of free nickel available for reduction (Bellemare, 1997). The overall deposition reaction is as follows:

$$3\ H_2PO_2^{-1} + 3\ H_2O + Ni^{+2} + SO_4^{-2} \rightarrow$$
$$3\ H_2PO_3^{-1} + H_2SO_4 + 2\ H_2 \uparrow + Ni^o.$$

The reduction of the nickel cation by the hypophosphite anion ($H_2PO_2^-$) was first described in Europe in 1846. In 1916, U.S. Patent 1,207,218 was granted for the electroless deposition of nickel on aluminum and other alloys using hypophosphite. This process, however, had several problems and was never commercialized. Researchers at the National Bureau of Standards (NBS), the forerunner of the National Institute of Standards and Technology, are generally credited with the discovery of electroless plating. In 1944, NBS researchers discovered electroless plating accidentally while investigating a new process for electroplating the bores of gun barrels (Duncan, 1995). The NBS researchers continued their investigations after World War II and were awarded U.S. Patent 2,535,283, for the process in 1950.

Several U.S. companies began investigating commercial uses of the process after the NBS findings were published in 1947. The General American Transportation Company (GATX) improved on the process and used it to plate the inside of rail tank cars. GATX's improved Kanigen process was licensed to some 25 other companies during the 1960's and early 1970's. In 1973, Elnic Inc., a metal finishing company in Nashville,TN, began promoting the use of high-phosphorus electroless nickel coatings to the oil and gas industry as a way of combating metal corrosion. Elnic's promotion was a huge success. During the 1970's, electroless coating of parts skyrocketed, rising by 10% to 15% per year, but leveled off in 1981. The leveling off was attributed to the collapse of oil prices and the migration of parts manufacturers to East Asia.

In 1995, at least 900 electroless plating facilities were operating in North America (Duncan, 1995). These facilities were largely concentrated along the three coasts or around the Great Lakes. Kanigen and other baths for medium-phosphorus coatings accounted for almost one-half of the solutions sold to the electroless plating market (Duncan, 1995). High-phosphorus coatings for memory disks accounted for another 24%. The fast growing low-phosphorus and specialty coatings market represented about 9%. Boron-reduced coatings represented less than 1% of the market.

The use of dialysis to treat spent electroless nickel solutions has helped the industry comply with new, increasingly stringent environmental regulations (Bellemare, 1997). Bath life can also be extended by several other regenerative processes. The aging of the solution is caused by the accumulation of reaction byproducts that reduce the nickel deposition rate and may prevent the nickel from properly adhering to the aluminum or other substrate.

Advanced Nickel-Based Batteries for Electric Vehicles.— Evercel, Inc., of Danbury, CT, has begun to mass produce rechargeable nickel-zinc batteries (Chin, 1999). The nickel-zinc batteries are being used on a limited basis to power bicycles, scooters, and small automobiles, as well as golf carts, lawn mowers, trolling motors for boats, and wheelchairs. The new nickel-zinc batteries will be made in Danbury and China.

In theory, a nickel-zinc battery should be superior to its nickel-cadmium and sealed-lead-acid counterparts for most vehicle and portable battery applications. The nickel-zinc cell has a greater energy density than either the nickel-cadmium or lead-acid cell. (Energy density is the ratio of cell energy to weight or volume, with data usually reported in watt-hours per kilogram or liter.) For a given amount of energy, a nickel-zinc battery weighs 50% less than an equivalent lead-acid battery and 30% less than a nickel-cadmium battery. The cycle life of the nickel-zinc battery ranges from 10,000 cycles with a 10% depth of discharge to 500 cycles with a 100% depth of discharge—three times longer than that of a conventional lead-acid battery (Chin, 1999). The nickel-zinc cell has a nominal voltage of 1.65 and could prove to be less expensive to manufacture than various nickel-metal hydride cells.

Evercel was spun off from Energy Research Corp. (ERC) on February 22, 1999 (Evercel, Inc., 1999). The researchers transferred from ERC have considerable expertise in the electrochemistry of nickel-cadmium, nickel-zinc, and silver-zinc batteries. The former ERC group had been working on rechargeable batteries and fuel cells since the early 1970's. Part of the ERC battery work was associated with U.S. Navy programs to develop better submarines and submergence rescue vehicles. From 1975 to 1983, the group manufactured large-sized silver-zinc batteries for submarines and submersibles. In 1979, the U.S. Department of Energy awarded ERC a contract to develop a nickel-zinc battery for EV's. Subsequent Government contracts resulted in the development of a variety of nickel-cadmium batteries for EV's and submarines. In 1998, the ERC group successfully demonstrated an advanced 12-kilowatt-hour nickel-zinc battery for EV's.

Outlook

In 1998 and early 1999, the lingering economic crises in East Asia and Russia continued to restrain the world price of nickel, as well as those of most other metals. In mid-1999, though, nickel prices began to recover from their lowest levels (in terms of constant dollars) in more than two decades. The long-term outlook for nickel consumption, which has not changed despite the crises, is extremely positive.

Demand for austenitic stainless steel will continue to drive the world nickel market for at least another 20 years. For the present, growing demand for stainless steel in the Americas and Europe has offset decreased demand in Japan and other key economies of East Asia. In recent months, the economies of some key Asian countries have improved considerably. In 1999, world consumption of all types of stainless steel will probably be at least 4% greater than the preliminary estimate of 16.8 million tons for 1998. Consumption is recovering faster than previously forecasted, especially in China, and could exceed 17.8 million tons in 2000. Beginning in 2000, stainless steel consumption is forecast to grow between 2% and 5% per year to the year 2006. After 2006, the growth rate could rise even more, perhaps reaching 9% at some point, if the Russian economy turns around. A rejuvenated Russian industry would begin consuming the large amounts of stainless sheet and plate required by a technologically advanced, market-oriented society. Surprisingly, there also is potential for increased consumption of stainless steel in the United States. Per capita consumption of stainless steel in the United States is less than one-half that in such countries as Italy, Japan, the Republic of Korea, and Taiwan (Inco Limited, 1998d, p. 4-12). U.S. industry is finding that it is cost effective to fabricate critical parts, machinery, and plumbing fixtures from stainless steel or even superalloys, despite the higher prices of these materials. The downtime, high-labor costs, and customer ill will incurred in replacing less expensive materials that have corroded or cracked far outweigh the initial cost of using more durable, nickel-containing steels and alloys.

Several forces are helping to sustain long-term growth in nickel consumption. First, faster transport, the explosive expansion of telecommunications systems, and the globalization of markets are forcing local communities to be more technologically astute. As a result, society as a whole is becoming increasingly dependent on products fabricated from sophisticated starting materials, many of which contain significant quantities of nickel. Second, a technologically advancing society is continually demanding new materials with improved resistance to corrosion and heat, again favoring nickel. Recent life-cycle studies have shown that costly, budget-wrecking bills for repairing highway bridges and similar infrastructure could have been avoided by substituting more expensive, but corrosion-resistant, stainless steel for traditional carbon steel in the original design (Whiteway, 1998). Third, the cost of producing a ton of stainless steel has fallen because of technological advances and improved economies of scale, making stainless more price competitive. Fourth, the population of the world is growing, increasing demands for quality stainless food-processing equipment, kitchenware, plumbing parts, and sinks.

Demand for nickel-bearing superalloys is expected to grow despite recent restructuring of the aerospace market. The aerospace industry has been gradually shifting from a defense-oriented market to one that is more evenly balanced between commercial and Government purchases. The globalization of markets and the ongoing telecommunications revolution are spurring long-distance travel and increasing demand for more sophisticated, faster, and quieter aircraft with a longer range.

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 quite small. The market for nickel-based batteries is expected to grow at least 6% per year during the next 10 years even if American automobile manufacturers decide to substitute lithium-ion cells for nickel-metal hydride cells in their third-generation EV's or first-generation hybrid vehicles.

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

TABLE 1
SALIENT NICKEL STATISTICS 1/

(Metric tons of contained nickel, unless otherwise specified)

	1994	1995	1996	1997	1998
United States:					
Mine production	--	1,560	1,330	--	--
Plant production	--	8,290	15,100	16,000	4,290
Secondary recovery from purchased scrap:					
From ferrous scrap	48,900	54,400	48,800	58,200 r/	52,900
From nonferrous scrap	9,690	10,200	10,500	10,200	10,400
Exports:					
Primary	7,420	9,750	13,100	16,400	8,440
Secondary	34,500	41,800	33,600	40,200	35,100
Imports for consumption:					
Ore	--	8,200	15,000	17,600	1,420
Primary	127,000	149,000	142,000	147,000	148,000
Secondary	6,070	7,930	8,060	11,000	8,500
Consumption:					
Reported:					
Primary	107,000	125,000	119,000	122,000 r/	116,000
Secondary (purchased scrap) 2/	58,600	64,500	59,300	68,400 r/	63,300
Total	166,000	189,000	179,000	190,000 r/	179,000
Apparent:					
Primary	134,000	151,000	147,000	154,000 r/	149,000
Secondary (purchased scrap) 2/	30,500	29,500	33,700	37,700 r/	37,000
Total	164,000	181,000	181,000	191,000 r/	186,000
Stocks, yearend:					
Government	26,800	19,800	15,900	8,530	2,600
Producers and traders	10,200	12,700	13,300	12,600	13,100
Consumer:					
Primary	7,290	8,230	8,850	10,300	10,300
Secondary	3,020	4,150	4,230	5,770 r/	5,450
Employment, yearend:					
Mine	1	17	8	7	7
Smelter	22	253	253	264	6
Port facility	3	25	23	22	1
Price, cash, London Metal Exchange:					
Per metric ton, average annual	$6,340	$8,228	$7,501	$6,927	$4,630
Per pound, average annual	$2.876	$3.732	$3.402	$3.142	$2.100
World: Mine production	932,000	1,040,000 r/	1,060,000 r/	1,120,000	1,140,000

r/ Revised.

1/ Data are rounded to three significant digits, except prices; may not add to totals shown.

2/ More nearly represents amount consumed than does apparent secondary consumption; internal evaluation indicates that apparent secondary consumption is considerably understated.

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

(Metric tons of contained nickel)

	1997	1998
Kind of scrap:		
Aluminum-base 2/	3,940	4,120
Copper-base	2,390	2,270
Ferrous-base 3/	58,200 r/	52,900
Nickel-base	3,880	3,970
Total	68,400 r/	63,300
Form of recovery:		
Aluminum-base alloys 4/	3,940	4,120
Copper-base alloys	3,820 r/	3,470
Ferrous alloys	58,200 r/	53,000
Nickel-base alloys	2,360 r/	2,720
Miscellaneous and unspecified	23 r/	1
Total	68,400 r/	63,300

r/ Revised.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Primarily used beverage cans and foundry borings and turnings.
3/ Primarily stainless and alloy steel scrap consumed at steel mills and foundries.
4/ Includes can scrap converted to ingot by toll smelters for sale on open market.

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

(Metric tons of contained nickel)

Form	1997	1998
Primary:		
Metal	91,100 r/	90,200
Ferronickel	22,500	16,800
Oxide and oxide sinter 2/	2,890	3,600
Chemicals	3,440	3,110
Other	1,650 r/	1,910
Total primary	122,000 r/	116,000
Secondary (scrap) 3/	68,400 r/	63,300
Grand total	190,000 r/	179,000

r/ Revised.
1/ Data are rounded to 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 1998, 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 1998	Grand total 1997 r/
Cast irons	230	W	W	(2/)	320	550	376	926	654
Chemicals and chemical uses	W	--	W	2,340	--	2,340	--	2,340	3,720
Electric, magnet, expansion alloys	516	(2/)	--	--	--	516	W	516	668
Electroplating (sales to platers)	16,300	--	W	78	(2/)	16,400	--	16,400	15,900
Nickel-copper and copper-nickel alloys	4,090	W	(2/)	--	W	4,090	2,800	6,890	6,530
Other nickel and nickel alloys	15,500	W	W	--	W	15,500	2,190	17,700	19,400
Steel:									
Stainless and heat resistant	23,900	15,800	2,320	--	35	42,000	51,200	93,200	105,000
Alloys (excludes stainless)	5,250	802	1,130	W	W	7,180	1,340	8,520	9,290
Superalloys	18,200	--	(2/)	(2/)	369	18,600	W	18,600	19,000
Other 3/	6,130	197	153	686	1,190	8,350	5,360	13,700	9,570
Total reported	90,200	16,800	3,600	3,110	1,910	116,000	63,300	179,000	190,000
Total all companies, apparent	XX	XX	XX	XX	XX	149,000	37,000	186,000	191,000

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.
3/ Includes batteries, catalysts, ceramics, coinage, other alloys containing nickel, and data indicated by symbol "W."

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

(Metric tons of contained nickel)

Form	1997	1998
Primary:		
Metal	7,660 r/	7,400
Ferronickel	1,390	881
Oxide and oxide sinter	355	1,370
Chemicals	702	445
Other	242	234
Total primary	10,300	10,300
Secondary (scrap)	5,770 r/	5,450
Grand total	16,100 r/	15,800

r/ Revised.
1/ Data are rounded to 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	1997 Quantity	1997 Value (thousands)	1998 Quantity	1998 Value (thousands)
Unwrought primary:				
Cathodes, pellets, briquets, shot	580	$4,020	1,210	$4,970
Ferronickel	6,950	53,000	918	10,500
Powder and flakes	917	14,500	1,080	14,200
Metallurgical-grade oxide	2,230	4,860	1,230	2,640
Chemicals:				
Catalysts	4,660	125,000	3,340	107,000
Salts 3/	1,030	11,600	675	6,900
Total	16,400	213,000	8,440	147,000
Unwrought secondary:				
Stainless steel scrap	27,700	231,000	22,400	176,000
Waste and scrap	12,400	59,700	12,700	54,400
Total	40,200	290,000	35,100	230,000
Grand total	56,500	504,000	43,500	377,000
Wrought:				
Bars, rods, profiles, wire	251	2,740	226	3,100
Sheets, strip, foil	420	7,590	173	3,120
Tubes and pipes	223	2,690	593	4,610
Total	892	13,000	992	10,800
Alloyed (gross weight):				
Unwrought alloyed ingot	4,910	67,900	5,970	82,800
Bars, rods, profiles, wire	5,950	99,000	6,650	108,000
Sheets, strip, foil	8,970	118,000	9,190	118,000
Tubes and pipes	1,270	29,600	1,170	26,300
Other alloyed articles	4,010	62,800	3,040	101,000
Total	25,100	377,000	26,000	436,000

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ The nickel contents are as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The salts category contains the following: chemical-grade oxide, sesquioxide, and hydroxide, 65%; chlorides, 25%; and sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel.
3/ Excludes nickel carbonate (see Schedule B 2836.99.9050).

Sources: Bureau of the Census and Journal of Commerce.

TABLE 7
U.S. EXPORTS OF NICKEL PRODUCTS IN 1998, 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 1998	Total 1997	Wrought nickel 4/
Australia	--	1	--	--	2	5	4	12	80	6
Belgium	--	108	--	(5/)	83	275	227	693	548	4
Canada	237	264	2	877	7,480	2,920	610	12,400	12,500	95
China	--	3	--	--	57	1,360	41	1,460	124	11
Colombia	8	1	--	--	--	14	6	29	19	1
Finland	--	1	--	--	5	--	22	28	30	1
France	25	22	--	(5/)	12	--	10	69	95	16
Germany	(5/)	60	--	3	389	149	65	666	802	14
India	20	18	729	--	179	171	71	1,190	2,510	1
Italy	--	4	2	--	--	1,440	37	1,480	114	2
Japan	1	44	82	2	1,130	1,270	1,130	3,650	5,670	7
Korea, Republic of	1	18	--	--	--	5,270	88	5,380	8,690	9
Mexico	651	295	12	88	1	64	628	1,740	4,750	173
Netherlands	89	6	--	--	29	423	58	605	515	12
South Africa	--	2	--	256	140	904	21	1,320	3,070	9
Spain	4	10	--	--	--	5,550	5	5,570	4,490	4
Sweden	--	9	--	--	3,020	233	2	3,260	2,790	5
Taiwan	(5/)	54	78	1	9	1,900	139	2,180	6,800	1
United Kingdom	46	34	13	--	121	132	60	406	551	83
Venezuela	19	3	--	--	30	--	223	275	525	4
Other	104	121	--	2	14	281	570	1,090	1,900	534
Total	1,210	1,080	918	1,230	12,700	22,400	4,010	43,500	56,500	992

1/ Data are rounded to 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/ Not included in "Total."
5/ Less than 1/2 unit.

Source: Bureau of the Census.

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

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

Class	1997 Quantity	1997 Value (thousands)	1998 Quantity	1998 Value (thousands)
Unwrought primary:				
Cathodes, pellets, briquets, shot	118,000	$825,000	120,000	$625,000
Ferronickel	13,500	87,700	12,800	64,000
Flakes	17	325	1	130
Powder	10,500	112,000	9,850	89,600
Metallurgical-grade oxide	1,940	16,000	2,140	10,400
Chemicals:				
Catalysts	1,320	51,700	1,080	43,300
Salts 3/	1,900	23,100	2,060	25,500
Total	147,000	1,120,000	148,000	858,000
Unwrought secondary:				
Stainless steel scrap	4,800	33,700	4,290	21,600
Waste and scrap	6,200	53,600	4,210	28,900
Total	11,000	87,300	8,500	50,500
Grand total	158,000	1,200,000	156,000	908,000
Wrought:				
Bars, rods, profiles, wire	348	4,420	299	3,770
Sheets, strip, foil	602	13,900	513	12,000
Tubes and pipes	22	921	7	240
Total	973	19,300 r/	819	16,000
Alloyed (gross weight):				
Unwrought alloyed ingot	3,730	38,600	2,250	30,500
Bars, rods, profiles, wire	5,440	70,400	5,840	70,800
Sheets, strip, foil	2,020	29,900	1,880	25,000
Tubes and pipes	1,990	42,700	1,600	35,200
Other alloyed articles	802	21,800	559	21,100
Total	14,000	203,000	12,100	183,000

r/ Revised.

1/ Data are rounded to three significant digits; may not add to totals shown.

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

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

Sources: Bureau of the Census and Journal of Commerce.

TABLE 9
U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY 1/

(Metric tons of contained nickel) 2/

Country	Cathodes, pellets, briquets (unwrought)	Powder and flakes	Ferro-nickel	Metal-lurgical grade oxide 3/	Waste and scrap	Stainless steel scrap	Chemicals	Total		Wrought nickel 4/
								1998	1997	
Australia	14,000	1,460	--	64	55	--	43	15,600	13,700	--
Austria	--	263	--	--	--	--	--	263	577	1
Belgium	--	63	--	--	87	--	383	533	451	2
Brazil	2,840	--	55	--	7	4	3	2,910	833	19
Canada	52,400	5,980	--	2,060	1,070	1,570	150	63,300	60,600	2
China	80	(5/)	--	--	3	--	139	222	131	2
Colombia	--	--	1,930	--	5	1	--	1,940	1,430	--
Dominican Republic	--	--	6,520	--	2	6	--	6,530	8,160	--
Finland	2,700	635	--	--	1	--	744	4,080	4,920	--
France	1,750	(5/)	--	--	633	36	157	2,570	2,320	52
Germany	(5/)	6	--	--	385	(5/)	225	616	780	553
Japan	--	15	--	(5/)	188	14	786	1,000	1,100	127
Mexico	--	7	--	--	101	1,480	29	1,620	2,380	(5/)
New Caledonia	--	--	3,960	--	--	--	--	3,960	3,470	--
Norway	21,000	--	--	--	19	--	--	21,100	24,100	--
Russia	22,300	580	--	--	2	--	--	22,900	25,600	(5/)
South Africa	508	20	5	--	2	--	34	569	1,470	--
United Kingdom	316	416	--	--	1,130	2	81	1,940	2,850	7
Zimbabwe	2,000	--	--	15	--	--	--	2,020	1,740	40
Other	75	405	374	1	521	1,170	363	2,910	1,850	14
Total	120,000	9,850	12,800	2,140	4,210	4,290	3,140	156,000	158,000	819

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ The nickel contents are assumed to be as follows: metallurgical-grade oxide from Australia, 90%; elsewhere, 77%. The chemicals category contains the following: chemical-grade oxide, sesquioxide and hydroxide, 65%; chlorides, 25%; sulfates, 22%. Other salts and various catalysts are assumed to be 22% nickel. Waste and scrap is assumed to be 50% nickel; stainless steel scrap, 7.5% nickel.
3/ Primarily oxide rondelles and sinter.
4/ Not included in "Total."
5/ Less than 1/2 unit.

Source: Bureau of the Census.

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

(Metric tons of nickel content)

Country	1994	1995	1996	1997	1998
Australia (content of concentrate)	78,962	98,467	113,134	123,372 r/	143,513
Botswana (content of ore milled)	19,041	18,088	21,900 r/ e/	19,900 r/ e/	21,000 e/
Brazil (content of ore)	27,706	29,124	25,245	31,936 r/	36,764
Burma (content of ore) e/	50	50	50	50	50
Canada (content of concentrate)	149,886	181,820	192,649	190,529	208,201
China e/	36,900	41,800	43,800	46,600 r/	48,700
Colombia (content of laterite ore)	26,141	24,194	27,700	31,230	29,422
Cuba (content of oxide, oxide sinter, sulfide) 3/	25,787	40,845	51,289	59,449 r/	65,300 e/
Dominican Republic (content of laterite ore)	50,146	46,523 r/	45,168 r/	49,152 r/	41,600 e/
Finland (content of concentrate)	7,652	3,439	2,136 r/	3,252	1,967
Greece (content of laterite ore)	18,821	19,947	21,600	18,419	16,985
Indonesia (content of ore)	81,175	88,183	87,911	71,127 r/	74,063
Kazakhstan e/	8,500	9,900 4/	7,000 r/	7,000 r/	6,000
Macedonia (content of ferronickel produced)	3,980	3,500	3,000 e/	3,000 e/	3,500 e/
New Caledonia (content of ore)	97,323	119,905 r/	122,486 r/	136,467 r/	129,200
Norway (content of concentrate)	3,328	3,386	3,135	2,454	2,959
Philippines	9,895	15,075	14,539	18,132	12,840
Russia e/	240,000	251,000	230,000	260,000	250,000
Serbia and Montenegro (content of ferronickel produced)	663 r/	962	2,556	2,500 e/	1,500 e/
South Africa (content of concentrate)	30,751	29,803	33,861	34,830	36,411
Ukraine (content of ferronickel produced) e/	1,400 4/	1,400	500	--	--
United States (content of local ore processed)	--	1,560	1,330	--	--
Zimbabwe (content of concentrate)	13,836	11,721	11,561	11,159 r/	12,749
Total	932,000	1,040,000 r/	1,060,000 r/	1,120,000	1,140,000

e/ Estimated. r/ Revised.

1/ World totals, U.S. data, and estimated data are rounded to 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 October 7, 1999.

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

4/ Reported figure.

TABLE 11

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

(Metric tons of nickel content)

Country and product 3/	1994	1995	1996	1997	1998
Albania: Metal e/	50	50	50	--	--
Australia: Unspecified	67,000	77,000	74,000	74,000	83,000 e/
Austria: Ferronickel e/	2,100	2,000 r/	2,000	2,000	1,800
Brazil: 4/					
Ferronickel	8,815	8,497	9,091	9,350 r/	8,077
Metal	7,795	7,179	7,849	8,849 r/	13,006
Total	16,610	15,676	16,940	18,199 r/	21,083
Canada: Unspecified 5/	105,144	125,311	130,136	131,639	146,715
China: Metal e/	31,300	38,900	44,600	43,300 r/	48,100
Colombia: Ferronickel	20,833	24,565	22,934	25,171	28,143
Cuba: Oxide sinter 6/	13,930	21,388	26,700	33,992 r/	38,661
Dominican Republic: Ferronickel	30,757	30,897	30,376	32,558	25,220
Finland:					
Metal	16,902	21,268 r/	28,815	34,228	41,500
Chemicals	4,192	4,280	4,508	4,990	4,518
Total	21,094	25,548 r/	33,323	39,218	46,018
France:					
Metal	8,841 r/	9,106 r/	9,070 r/	8,750 r/	9,778
Chemicals	1,200 r/	1,199 r/	2,101 r/	1,952 r/	2,000 e/
Total 7/	10,041	10,305 r/	11,171 r/	10,702 r/	11,778
Greece: Ferronickel	16,197	17,164	17,801	17,610 r/	15,005
Indonesia: Ferronickel	5,745	10,735	9,553	9,999	8,452
Japan:					
Ferronickel	50,186	69,876	66,796	72,097 r/	69,202
Metal	25,311	26,824	26,564	26,889	29,397
Oxide sinter	34,711	35,966	35,000	26,899 r/	25,435
Chemicals	2,400	2,297	2,323	2,536	2,511
Total	112,608	134,963	130,683	128,421 r/	126,545
Korea, Republic of: Metal	(8/)	(8/)	(8/)	(8/)	(8/) e/
Macedonia: Ferronickel e/	3,980 9/	3,500 9/	3,000	3,000	3,500
New Caledonia: Ferronickel	39,488	42,200	42,173 r/	44,312 r/	44,491
Norway: Metal	67,955	53,237	61,582	62,702	70,152
Poland: Chemicals 10/	358	374	359	364	376
Russia: e/ 11/					
Ferronickel	9,800	14,000	10,000	10,000	10,000
Metal	164,500	181,000	170,000 r/	210,000	208,000
Oxide sinter	4,600	4,100	8,000 r/	8,000	10,000
Chemicals	2,000	2,000	2,000	2,000	2,000
Total	180,900	201,100	190,000	230,000	230,000
Serbia and Montenegro: Ferronickel	663 r/	962	2,556	2,500 e/	1,500 e/
South Africa: Metal 12/	30,751	29,803	33,362 r/	33,700 r/	36,411
Sweden: Metal e/	500	500	--	--	--
Taiwan: Metal	(8/)	(8/)	(8/)	(8/)	(8/) e/
Ukraine: Ferronickel e/	1,400	1,400	500	--	--
United Kingdom: Metal	28,386 r/	35,156	38,561	36,091 r/	39,050
United States: Ferronickel	--	8,290	15,100	16,000	4,290
Zimbabwe: Metal 13/	13,516	10,864	9,694 r/	10,300 r/	10,135
Other: Metal 14/	4,984	4,641	6,518 r/	7,346 r/	7,306
Grand total:	826,000	927,000 r/	954,000 r/	1,010,000	1,050,000
Of which:					
Ferronickel	190,000	234,000 r/	232,000	245,000 r/	220,000
Metal	401,000	419,000 r/	437,000 r/	482,000 r/	513,000
Oxide sinter	53,200	61,500	69,700 r/	68,900 r/	74,100
Chemicals	10,200 r/	10,200 r/	11,300 r/	11,800 r/	11,400
Unspecified	172,000	202,000	204,000	206,000	230,000

e/ Estimated. r/ Revised.

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

2/ Table includes data available through October 22, 1999.

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/ Brazil produced nickel carbonate (an intermediate product), in metric tons: 1994--8,930; 1995--8,051; 1996--9,210; 1997--10,487 (revised); and 1998--13,133.

5/ Nickel contained in products of smelters and refineries in forms, which are ready for use by consumers. Figures include the nickel content of nickel oxide sinter exported to the Republic of Korea and Taiwan. See footnote 8.
6/ Cuba also produces nickel sulfide but, because it is used as feed material elsewhere, it is not included to avoid double counting. Output of processed sulfide was as follows, in metric tons of contained nickel: 1994--11,855 (revised); 1995--19,457; 1996--24,589; 1997--25,457 (revised); and 1998--26,881 (preliminary). See table 12.
7/ Reported by Eramet for Sandouville. Excludes secondary production from spent rechargeable batteries.
8/ Nickel metal production for the Republic of Korea and Taiwan are not included because the production is derived wholly from imported metallurgical-grade oxides and to include them would result in double counting. Metal estimates are as follows, in metric tons: the Republic of Korea: 1994-96--10,000; 1997--18,000 (revised); and 1998--20,000; and Taiwan: 1994-96--10,000 and 1997-98--10,500.
9/ Reported figure.
10/ Nickel content of nickel sulfate ($NiSO_4 6H_2O$). Most of the nickel sulfate was a byproduct of the concentrating, smelting, and refining of domestically mined copper ores. Some production, however, may have been derived from imported nickeliferous raw materials that were blended with the domestic copper concentrates.
11/ Includes production from sulfidized concentrates shipped from Cuba for toll refining.
12/ Figures include nickel sulfate exported for toll refining.
13/ Production from domestic nickel ore. Figures exclude production from imported Botswanan matte, as well as from South African nickel sulfates.
14/ Cross-border tolling.

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

(Metric tons of nickel content)

Country	1994	1995	1996	1997	1998
Matte:					
Australia 2/	24,660	26,554	28,768	37,010	47,458
Botswana	19,042	18,089	22,095	20,157	22,851
Brazil 3/	--	--	--	1,180	4,670
Canada e/ 4/	38,000	43,000	50,000	45,000	52,000
Indonesia	48,446	49,333	49,000	33,654	35,697
New Caledonia	10,641	10,143	11,239	10,580	12,011
Russia e/ 5/	10,700	699	320	366	98
Total	151,000	148,000	161,000	148,000	175,000
Other: Cuba, sulfide precipitate 6/	11,855	19,457	24,589	25,457	26,881

e/ Estimated.
1/ Table includes data available through October 20, 1999. Data represent nickel content of matte and other intermediate materials produced for export.
2/ Total matte production on a contained nickel basis, in metric tons, was as follows: 1994--67,000; 1995--77,000; 1996--74,000; 1997--85,800; and 1998--100,100.
3/ The Fortaleza smelter was commissioned in December 1997. All output is being shipped to Finland for further processing.
4/ Estimated nickel content of reported exports.
5/ Export figures reported by importing countries: primarily France and Norway. Exports to Norway were estimated to have a nickel content of 40%.
6/ Corrected for coproduct cobalt.

FIGURE 1

NICKEL: LONDON METAL EXCHANGE CASH PRICE AND STOCKS

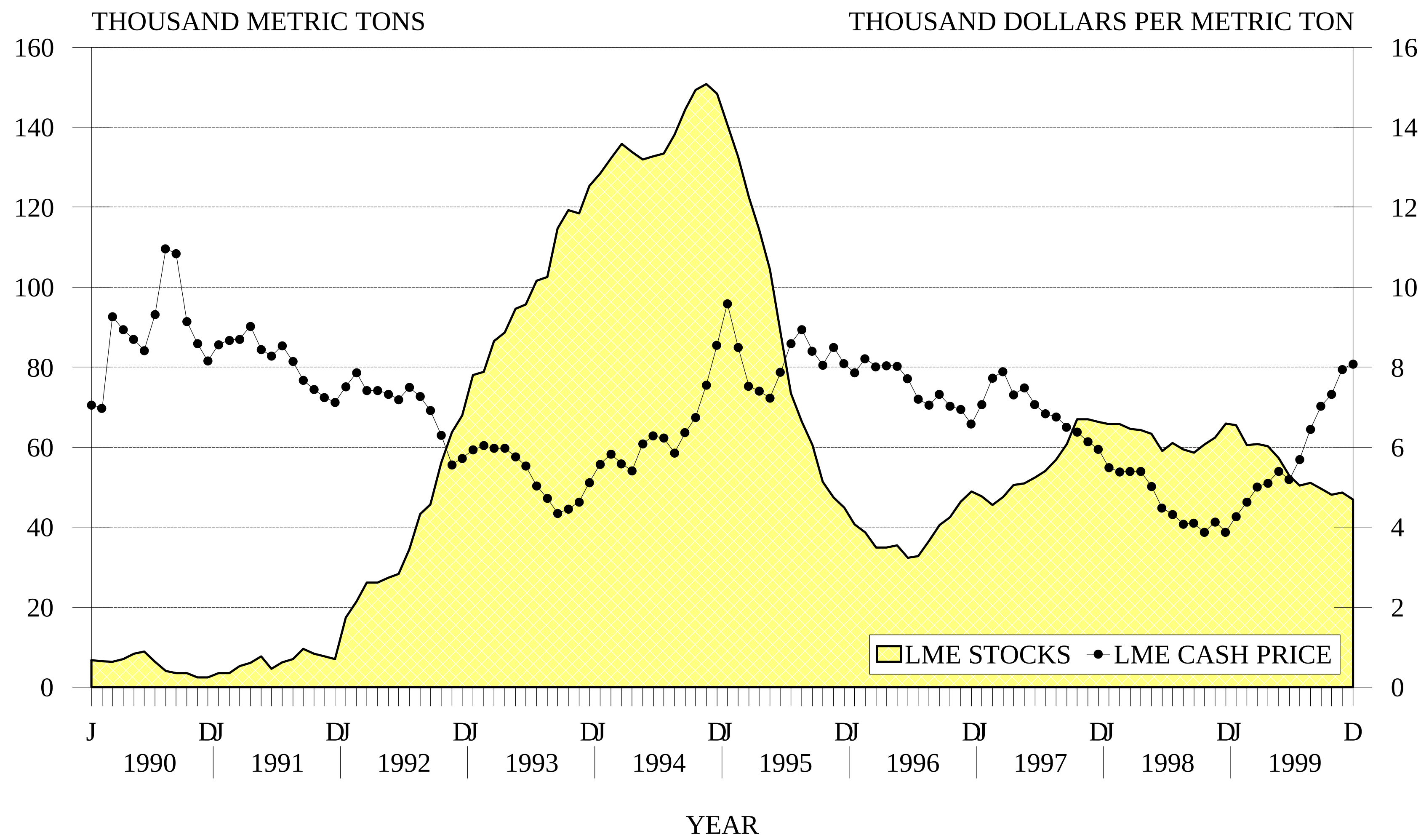
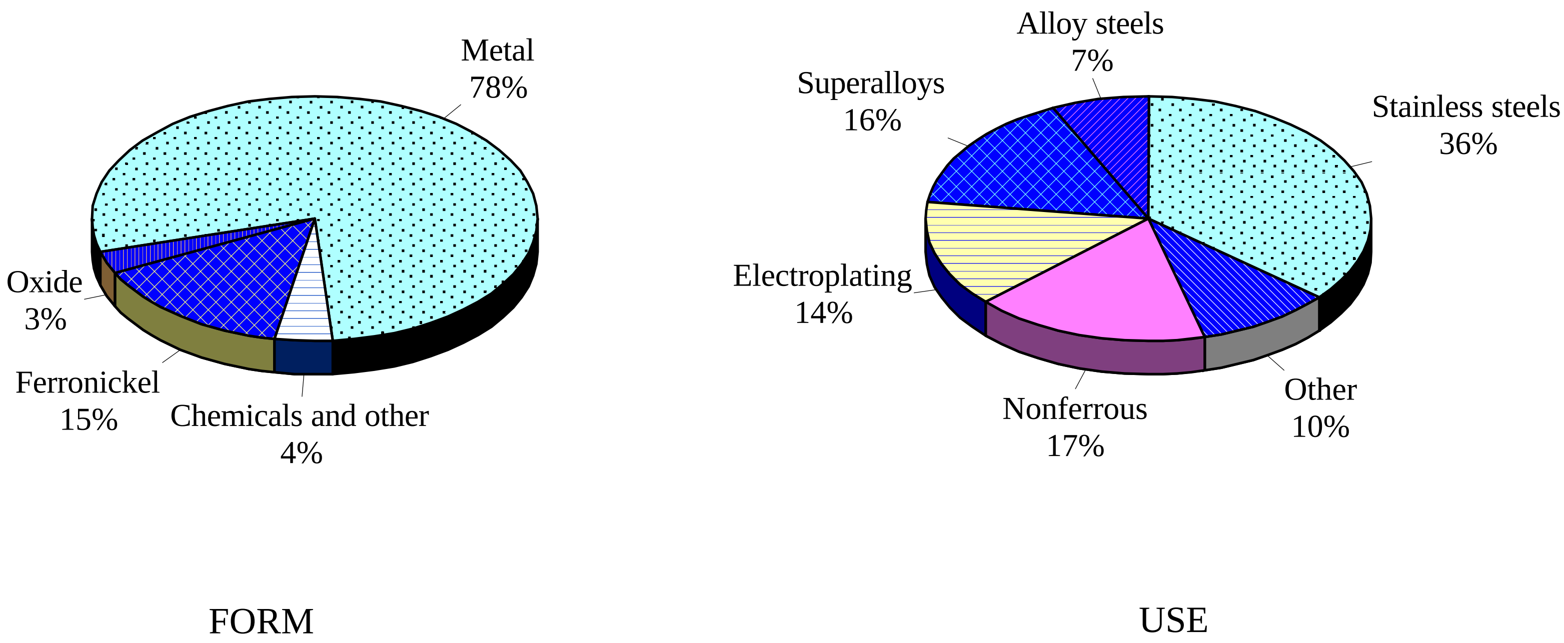


FIGURE 2

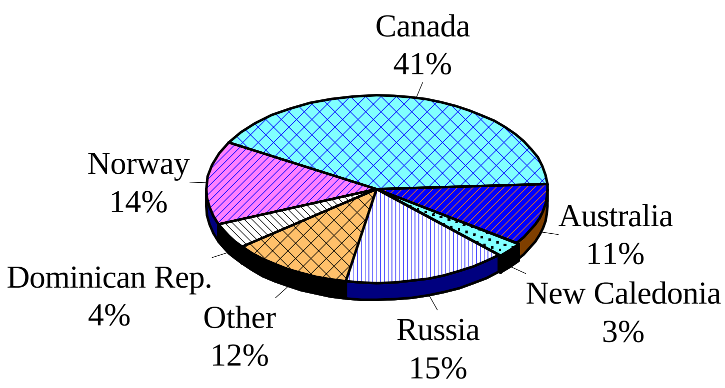
U.S. PRIMARY NICKEL CONSUMPTION BY FORM AND USE, IN 1998



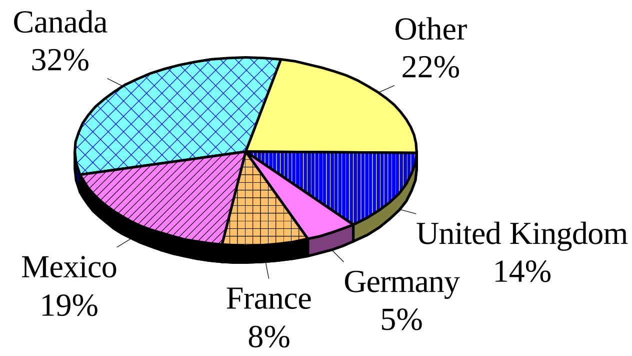
PRIMARY CONSUMPTION: 116,000 METRIC TONS

FIGURE 3

U.S. PRIMARY AND SECONDARY NICKEL IMPORTS BY COUNTRY, IN 1998



PRIMARY: 148,000 METRIC TONS



SECONDARY: 8,500 METRIC TONS