# **NICKEL**

## By Peter H. Kuck

On August 21, 1996, Inco Limited acquired Diamond Fields Resources Inc. for \$3.1 billion. The acquisition gave Inco control of the immense Voisey's Bay nickel-copper-cobalt deposit in Labrador. The deposit was discovered in 1993 and is the most significant Canadian base metal find in more than 30 years. Exploration drilling, which is still in the early stages, already has delineated four ore zones, with indicated resources totaling at least 150 million metric tons of sulfide ore. The Voisey's Bay project, the modernization of operations at Sudbury, Ontario, and the new Raglan Mine in northern Quebec should solidify Canada's position as a leading supplier of nickel far into the 21st century.

Russia, the world's largest producer of nickel, continued to privatize and restructure all of its nickel mining and smelting operations. In 1996, RAO Norilsk Nickel accounted for 93% of total Russian production. Modernization of the company's three smelters has been hampered by the enormous amounts of capital required. Efforts were underway to borrow a significant portion of the necessary funds from potential financial backers in Scandinavia.

In December 1994, Sherritt Inc. and the Government of Cuba formed a joint venture to refine and market nickel mined at Moa. Since then, Sherritt has undergone a restructuring, changed its name to Viridian Inc., and spun off its holdings in the joint nickel venture. The divested company, Sherritt International Corp., continued to modernize the Moa operation. The bulk of the sulfide precipitate was being shipped to Sherritt International's refining complex at Fort Saskatchewan, Alberta.

The price of nickel metal on the London Metal Exchange (LME) declined gradually during 1996, bottoming out in December at \$6,581 per metric ton (\$2.985 per pound). The monthly average for December 1995 had been \$8,091 per metric ton (\$3.670 per pound). The decline in price occurred even though producers' stocks in the Western World declined at the same time from 98,700 tons to 85,000 tons. Also, stocks in LME warehouses never exceeded 50,000 tons and were far below the record high of 151,254 tons reached on November 24, 1994, when the price was \$7,625 per metric ton (\$3.459 per pound).

World nickel supplies continued to keep pace with the growing demand for the metal. Mine development or expansion projects were underway in Brazil, Indonesia, Manitoba, New Caledonia, Ontario, Quebec, Venezuela, and Western Australia. In addition to Labrador, exploration teams were active in Côte d'Ivoire, Cuba, Finland, Greenland, Russia, South Africa, and Tanzania.

In 1996, apparent U.S. demand for primary nickel was 2% less than that of 1995. U.S. demand for stainless steel, in

contrast, was up 4%. About 34% of U.S. stainless demand was being met by imports. U.S. stainless production decreased 9% during the same period. Smaller declines in stainless production were reported by the European Union (-4%) and Japan (-1%) (American Iron and Steel Institute, 1997a; International Nickel Study Group, 1997b).

Stainless steel production remained depressed in Russia because of that country's continuing economic restructuring. In other parts of the world, though, stainless steel production has been steadily growing. Capacity was being added in the Republic of Korea, South Africa, and Taiwan. By 1997, the combined output of austenitic stainless steel from the Republic of Korea and Taiwan is expected to exceed that of North America. Stainless steel now accounts for about 66% of primary nickel demand in the entire world (Anderson, 1996; Upton, 1997). Another 5% is consumed in the production of alloy steels. Over the last 20 years, stainless steel production in the Western World has been growing at an average rate of 4.5%, down somewhat from the long-term trend of 6.0%.

Demand for primary nickel by battery manufacturers continues to grow, although the tonnages involved are an order of magnitude smaller than those for stainless steel. Rechargeable nickel-cadmium and nickel-metal hydride batteries are in strong competition with one another for handheld power tools, cellular telephones, laptop computers, and camcorders. The bulk of the batteries imported into the United States are made in Japan, Mexico, China, France, or Hong Kong (in descending order of market share).

PSA Peugeot-Citroën and Renault of France began producing electric vehicles (EV's) on an extended basis. The new vehicles were being powered by nickel-cadmium batteries made by SAFT S.A. Honda Motor Co. Ltd. was planning to begin leasing nickel-metal hydride-powered EV's to California fleet owners in 1997.

### **Legislation and Government Programs**

Cuban Embargo.—Relations between Cuban nickel producers and the U.S. Government deteriorated during 1996. Cuba has the largest reserve base of nickel-bearing laterites in the world. Three mining and smelting complexes are currently producing nickel on the island. Nicaro and Punta Gorda produce nickel oxide by the ammonium-carbonate leach process and are operated by La Compania General de Niquel S.A. (General Nickel), a parastatal enterprise (Suttill, 1994). The third, Moa, produces a nickel-cobalt sulfide precipitate which is shipped to Canada for further processing. This third complex is operated as a joint venture of Sherritt International Corp. and

General Nickel. The Cuban Government and Sherritt are equal partners in the Moa venture. Construction of a fourth plant, Las Camariocas, was suspended about 5 years ago after key Eastern European partners withdrew from the project. All four plants are in Holguín Province. None of the nickel production can be marketed in the United States because of the U.S. embargo against Cuba. Importation of Cuban nickel is prohibited under the Cuban Assets Control Regulations, 31 CFR, part 515. There were also bilateral agreements on this issue between the U.S. Government and several major nickel-consuming nations.

On March 12, 1996, the President signed into law legislation designed to discourage foreign investment in Cuba. The new law was entitled "The Cuban Liberty and Democratic Solidarity (LIBERTAD) Act of 1996" (Public Law 104-114). The LIBERTAD Act codified the existing executive orders that imposed an economic embargo on Cuba. The LIBERTAD Act gives American citizens, whose property was expropriated by the Cuban Government, the right to sue in U.S. courts any foreign company that makes 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. The European Union responded by taking the whole matter of the Cuban embargo to the newly formed World Trade Organization.

At least two other prominent nickel producers, besides Sherritt, have entered into agreements with Cuban parastatal organizations since 1993. Gencor Limited of South Africa recently began evaluating a lateritic deposit in the San Felipe area of Camaguey Province. In September 1994, Western Mining Corporation Holdings Limited of Australia (now WMC Limited) signed a memorandum of understanding with Commercial Caribbean Nickel S.A. to evaluate and develop the Pinares de Mayari West lateritic deposit in Holguín Province. The Pinares deposit reportedly contains more than 200 million tons of ore exceeding 1% nickel and 0.1% cobalt (Western Mining Corporation Holdings Limited, 1995; WMC Limited, 1997). At least two companies have approached the Government of Cuba about resuming work on the mothballed Las Camariocas project.

*Environmental Regulations*.—In 1994, legislation was introduced in the Congress to make the reclamation of spent consumer batteries (i.e., household batteries, batteries for portable office equipment, and batteries for EV's) more economically feasible and remove regulatory burdens from the battery recycling industry.

A modified version of the legislation pertaining specifically to spent nickel-cadmium batteries was taken up again by the 104th Congress, passed, and signed into law by the President on May 13, 1996. The new law was entitled "The Mercury-Containing and Rechargeable Battery Management Act of 1996" (Public Law 104-142). Title I of the act established uniform national labeling requirements for nickel-cadmium, small sealed lead-acid, and certain other regulated batteries. Each battery or battery pack must bear a recycling symbol and a recycling phrase appropriate to its electrode chemistries. The labeling requirements are similar to ones already adopted by

Japan. Domestic battery manufacturers and importers must be in complete compliance with the labeling requirements by May 1998. Title I also provided for the streamlining of regulations governing battery collection and recycling. Voluntary industry programs are to be encouraged, and regulatory requirements are to be minimized so that the collection and recycling programs can be efficient and cost-effective.

The U.S. Environmental Protection Agency (EPA) is responsible for enforcing most of the provisions of the act. EPA can now promulgate regulations requiring manufac-turers of rechargeable consumer products to redesign their products, if safety is not compromised, so that the batteries inside can be more easily removed. The agency also has been directed to work with battery manufacturers, manufac-turers of consumer products, and retailers in disseminating proper handling and disposal information on batteries to the general public. The legislation had the support of most battery manufacturers and many retailers. (See Current Research and Technology section of this review.)

In 1995, EPA introduced new regulations designed to encourage environmentally sound recycling of nickel-cadmium batteries and keep them out of the municipal waste stream. The new regulations were part of a much larger package of regulations known as the "Universal Waste Rule." At the beginning of 1996, 13 of the 50 States had laws regulating nickel-cadmium and other rechargeable batteries. Nine of the thirteen States also required the collection of rechargeable batteries. The Portable Rechargeable Battery Association, a nonprofit trade association composed of more than 100 manufacturers, distributors, assemblers, users, and sellers of small rechargeable batteries, was in the process of setting up a nationwide collection and recycling system.

Several States, faced with increasing air pollution problems, have taken action on their own to reduce exhaust emissions from automobiles, similar vehicles, and other self-propelled machinery powered by internal combustion engines. The manufacturing and sale of EV's were being encouraged because EV's appear to be at least a partial solution to some of these problems, especially in metropolitan areas. On March 29, 1996, the California Air Resources Board (CARB) unanimously approved a staff recommendation to restructure the board's electric vehicle mandate (Rechtin, 1996; Rose, 1996). The staff recommendation was based in part on the findings of an independent battery technical advisory panel. CARB still wants to have 800,000 EV's and other zero-emission automobiles on California highways by the year 2010. However, the board decided to drop its earlier requirement that seven leading automobile manufacturers begin selling EV's in California in 1998. The manufacturers involved were Chrysler Corp., Ford Motor Co., General Motors Corp., Honda Motor Co., Mazda Motor Corp., Nissan Motor Co., and Toyota Motor Corp. The old regulations would have required 2% of all automobiles sold in California in 1998 to be EV's or some other type of zeroemission vehicle. This percentage was to escalate to 5% beginning with the 2001 model year. The two requirements were dropped after the auto manufacturers requested additional time to resolve technological problems. The auto manufacturers are particularly concerned that the limited range of the first generation of EV's will seriously limit their marketability.

In exchange for being released from the 1998 requirement, the manufacturers have agreed to meet the existing 10% requirement for the year 2003 and to begin selling low-emission vehicles—the so-called 49-State car—in the 2001 model year. The board directed its staff to draw up a memorandum of agreement between the State of California and each of the seven auto manufacturers. Special credits will be issued to manufacturers who market EV's before 2003.

Only four battery chemistries were being used in the initial production runs. Chrysler, Ford, and General Motors were all planning to initially use advanced lead-acid battery packs. Honda and Toyota are currently testing nickel-metal hydride packs. General Motors is also considering offering a nickel-metal hydride battery pack as an option on its first mass-marketed EV—the EV1.

Several European EV's could conceivably carve out a niche in the California market. PSA Peugeot Citroën and Renault already have begun to produce nickel-cadmium powered EV's on a large scale in France. In October 1995, SAFT SA inaugurated a nickel-cadmium EV battery plant in Bordeaux, France, that can initially produce 5,000 batteries per year. The International Metals Reclamation Co., Inc. (Inmetco) now has equipment at its Ellwood City facility that can reclaim spent nickel-cadmium and nickel-metal hydride batteries from EV's on a limited basis (Hanewald, Schweers and Liotta, 1996). Deutsche Post AG (the German postal service), Daimler-Benz AG (Mercedes-Benz), and several other northern European enterprises are working together with Electric Fuel Limited of Israel to develop a refuelable zinc-air battery.

The production of only 10,000 nickel-cadmium or nickel-metal hydride powered EV's for the California market would require roughly 1,800 tons of nickel. According to Toyota officials, the nickel-metal hydride battery pack offers 1.5 times the energy storage capacity of lead-acid batteries while being more than 10% lighter (Kimberley, 1995).

On December 13, 1996, the President of the United States signed an Executive order designed to encourage the use of EV's and other alternative fueled vehicles (AFV's) in metropolitan areas of the country (Presidential Documents, 1996). Executive Order 13031 (Federal Alternative Fueled Vehicle Leadership) required each Federal Agency to immediately develop and implement plans for acquiring alternative fueled vehicles. In fiscal year (FY) 1997, 33% of the general-use vehicles acquired were to be AFV's. This percentage increases to 50% in FY 1998, 75% in FY 1999, and 75% for subsequent years. The Executive order was designed to reduce U.S. dependence on imported oil, to provide an economic stimulus to domestic industry, and to improve air quality in various parts of the country. Some industry analysts expect the order will spur production of nickel-metal hydride batteries for EV's in the United States. The effect of the order on the use of enhanced nickel-cadmium batteries in U.S. vehicles was uncertain. No U.S. automobile manufacturer has announced plans to introduce a nickel-cadmium powered automobile in the near future. However, nickel-cadmium batteries are being used in at least two European and one Japanese EV models. Nickel-cadmium batteries offer some advantages over advanced lead competitors in terms of reliability, longevity, energy density, and recyclability. Nickel-cadmium batteries also have the potential to capture a large part of the propulsion market for electric motor scooters, electric bicycles, and electric wheelchairs. Tokyo R&D Co. Ltd. recently began selling a nickel-cadmium powered electric scooter. The scooter retails in Japan for ¥596,000 or about \$5.030.

Defense Stockpile Sales.—The Defense Logistics Agency (DLA) continued to sell nickel from the National Defense Stockpile (NDS). The Government had 33,760 tons of nickel in inventory when the sales started on March 24, 1993. All 33,760 tons was some form of electrolytic metal except for 399 tons contained in 520 tons of oxide of Cuban origin. 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). In 1996, nickel was being offered at monthly auctions and through privately negotiated long-term solicitations.

By the end of 1995, uncommitted stocks had shrunk to 17,010 tons—all of it metal. An additional 2,787 tons was awaiting pickup on December 31, 1995, for a total physical inventory of 19,797 tons. In 1996, DLA warehouses turned over 3,938 tons to purchasers, leaving uncommitted stocks of 10,257 tons on December 31. Total yearend stocks also included 5,602 tons of committed material, for a grand total of 15,859 tons. At the currently authorized rate of sales, the remaining stocks of metal should be exhausted by mid-1999.

#### **Production**

The United States has only one primary nickel producer—the Glenbrook Nickel Co. of Riddle, OR. In 1996, Glenbrook produced 15,070 tons of nickel contained in ferronickel—a record high tonnage for the Douglas County operation. The mining and smelting complex is a 50-50 joint venture of Cominco American Inc. and Cominco Resources International Ltd. The smelter has a design capacity of 16,000 tons per year of nickel in ferronickel and uses the Ugine reduction process to make high-grade granulated ferronickel from lateritic ores. 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. Glenbrook's ferronickel has a considerably higher nickel content (48% to 52%) than most competing products (19% to 41%). The company was planning to upgrade the smelter baghouse and dust handling system so that the complex would have more operational flexibility and still fully comply with the air quality permit issued by the State of Oregon (Cominco Ltd., 1997).

Société Minière du Sud Pacifique of New Caledonia has a long-term contract with Glenbrook to supply most of the lateritic ore consumed by the smelter. The imported ore is unloaded at Glenbrook's Coos Bay port facility in Coos County and dried at dockside before being trucked to Riddle. The remainder of the smelter feed comes from the company's mine on Nickel Mountain that overlooks the smelter. The nickel content of the New Caledonian ore is significantly higher than that from Nickel Mountain (2.3% vs. 1.25% nickel on a dry basis). At the end of 1996, the Nickel Mountain Mine had only 230,000 tons of reserves remaining. However, additional resources of similar grade are available from other lateritic deposits in Douglas County and neighboring Josephine County. Cominco also has 2.5 million tons of probable resources and 6.0 million tons of possible resources at its Buena Vista deposit in Guatemala. The Guatemalan ore averages 2.2% nickel and, if prices warranted, conceivably could be trucked to Puerto de San José and from there shipped by vessel along the Pacific coast to Coos Bay.

Inmetco, a subsidiary of Inco Limited, 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. In 1996, Inmetco produced about 21,400 tons of chromium-nickel-iron alloy containing 15,100 tons of iron, 3,400 tons of chromium, 2,600 tons of nickel, and 330 tons of molybdenum from material that would otherwise be disposed of in landfills (The International Metals Reclamation Co., Inc., 1997).

Inmetco now accepts 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 nickelcadmium batteries whenever feasible. Industrial nickelcadmium batteries are handled differently than their smaller household counterparts. Workers dismantle the industrial batteries using power saws, drain off the electrolyte, and visually segregate the nickel plates from their cadmium counterparts. The nickel plates are shredded and fed directly into the main rotary hearth furnace, while the cadmium plates go into an electric-powered distillation furnace where the cadmium is fumed off. The much smaller, consumer cells have to be shredded and then thermally oxidized to remove their plastic components before they can be charged into the distillation furnace. The nickel and iron-rich residue left in the distillation furnace is later fed into the main chromium-nickel-iron feedstream.

Limited quantities of nickel also were recovered at some copper and precious metals refineries and a few plants that reclaim spent catalysts. The Stillwater Mining Co. was setting up a recovery circuit for nickel-cobalt sulfides at its platinum-group metals concentrator in Columbus, MT.

#### Consumption

Demand for primary nickel in the Western World weakened

slightly and was estimated to be about 838,000 tons—down 7% from the all time high of 900,000 tons reached in 1995 (International Nickel Study Group, 1997a). However, the tonnage was still 7% more than the previous record of 785,000 tons set in 1994 (revised figure). U.S. apparent consumption of primary nickel was 149,100 tons, or about 18% of Western demand. U.S. industry consumed an additional 59,200 tons of nickel in scrap. Both U.S. and world demand continued to be driven by the stainless steel industry, which accounted for 40% of primary nickel demand in the United States and more than 60% of equivalent world demand.

Since 1991, major restructuring, adoption of more efficient work practices, and the introduction of new technology have improved the competitiveness of the U.S. specialty steel industry. Production of raw stainless and heat-resisting steel in the United States decreased slightly to 1.87 million tons and was 9% less than the corresponding record-breaking figure of 2.06 million tons for 1995. Nickel-bearing grades accounted for 1.21 million tons, or 63% of the total stainless production for 1996 (American Iron and Steel Institute, 1997a). Net shipments of all types of stainless totaled 1.73 million tons (American Iron and Steel Institute, 1997b). Shipments of sheets and strip increased 4% to 1.25 million tons, breaking the previous record of 1.20 million tons set in 1995. The next largest category was plate [flat product 4.8 millimeter (3/16 inch) or more in thickness]. Shipments of plate were 220,000 tons, 9% less than that of 1995. Together, plate and sheet accounted for 85% of total net shipments, a slightly higher percentage than in 1995.

Stainless steel sheet is used in the manufacture of a wide range of consumer products, including household appliances, kitchen facilities, machinery, and medical equipment. Plate is primarily used in the fabrication of chemical reaction vessels and similar heavy-duty industrial equipment. The chemical, food and beverage, petrochemical, pharmaceutical, pulp and paper, and textile industries are all large consumers of stainless plate.

In 1996, U.S. consumption of primary nickel in superalloys decreased 7% because of problems 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 significant consumers of nickelchromium-cobalt and nickel-chromium-iron alloys. The last few years have been difficult for U.S. aerospace companies because of declining defense spending and a protracted airline recession. The aerospace market is now shifting from a governmentdominated market to one driven primarily by commercial customers. The U.S. Government now accounts for only 50% of domestic aerospace products and services, compared with 75% a decade ago. Sales by the U.S. aerospace industry rose 8% to \$117 billion after falling in 1995 to the lowest level in 9 years (Aerospace Industries Association of America, Inc., 1996).

For the second year in a row, Boeing Co. and McDonnell Douglas Corp. built up their backlog of orders for civil jet transports. A total of 595 net orders for large civil jet transports were received in 1996, compared with 421 in 1995. Actual

shipments also increased between 1995 and 1996, rising from 256 aircraft to 269. On December 31, 1996, the companies had a combined backlog of 1,617 aircraft, up from 1,291 at yearend 1995. Aerospace sales were expected to rise 11% in 1997 and improve even more in 1998.

In early 1996, Allegheny Ludlum Corp. and Teledyne Inc. agreed to merge (Holusha, 1996; Norton and Pasztor, 1996). Allegheny Ludlum, one of the larger producers of stainless steel in the Western Hemisphere, had been interested in acquiring the specialty metals operations of Teledyne for more than 10 years. Teledyne was, at the time, a conglomerate of defense and consumer products businesses, with strong segments in aviation, electronics, and specialty metals.

The new entity was called Allegheny Teledyne Inc. At yearend 1996, the combined company had a market capitalization of roughly \$4 billion and assets of \$2.6 billion. Sales totaled \$3.8 billion for the year. About 60% of total revenues, or \$2.3 billion, came from sales of specialty metals. Another 22% of revenues was generated by sales of equipment and services to the aerospace and electronics industries. The merger took effect on August 15, 1996, following approval by the shareholders of both companies. The new corporation was headquartered in Pittsburgh, PA, together with the specialty metals operations.

The principal force driving the merger was the financial synergies that should be created after the specialty metals operations of the two companies are fully integrated. Allegheny Ludlum accelerated its merger efforts after New York-based WHX Corp. offered to take over Teledyne for \$1.2 billion in late 1994. WHX owns Wheeling-Pittsburgh Steel Corp., the ninth largest integrated steel producer in the United States. The last offer made by WHX was \$1.78 billion. The merger made Allegheny Teledyne one of the larger specialty metals producers in the world.

Demand for nickel-cadmium and nickel-metal hydride batteries continues to grow throughout all of North America and is being spurred by the rapidly expanding U.S. program for recycling industrial and household batteries. Both battery types are widely used in hand-held power tools and a myriad of portable electronic devices, including compact disc players, pocket recorders, camcorders, cordless telephones, cellular telephones, scanner radios, and laptop computers. The United States imported \$673 million worth of nickel-cadmium batteries. The bulk of the imported batteries were made in Mexico, Japan, China, or Hong Kong (in descending order of market share).

#### Stocks

The combined stocks of primary nickel maintained in the United States by foreign producers and metal-trading companies with U.S. sales offices decreased 12% during the year. At yearend, these stocks represented 27 days of apparent primary consumption.

In recent years, LME stocks have far exceeded U.S. consumer stocks. However, the gap sharply narrowed during

the first half of 1996. On December 23, 1996, LME warehouses held 49,548 tons of nickel metal, of which 45,498 tons or 91.8% was in the form of cut cathodes. The remaining 8.2% consisted of 4,014 tons of briquets and 36 tons of pellets. The 49,548-ton total represented a drop of 67% 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 in Rotterdam.

#### **Prices**

Nickel prices peaked in January 1995 at \$9,593 per ton (\$4.351 per pound) after recovering from a 6-year low in September 1993. Since then, prices have fallen considerably. In 1995, nickel demand in the Western World exceeded supply by approximately 66,000 tons. However, in 1996, the situation was reversed, with supply exceeding demand by about 38,000 tons. The price decline was spurred by massive exports of cathode and carbonyl pellets from Norilsk Nickel. Internal demands within Russia for hard currency and the continued depressed state of the Russian stainless steel industry encouraged Norilsk to export the bulk of its production to the West.

The highest prices were recorded in February, with the monthly LME cash price reaching \$8,216 per ton (\$3.727 per pound). From then on, prices gradually weakened, eventually dropping to \$6,581 per ton (\$2.985 per pound) in December. The last weekly price (for the week ending December 27, 1996) was \$6,438 per ton (\$2.920 per pound). The average annual price was \$7,501 per ton (\$3.402 per pound). The annual price was about 9% lower than the 1995 average of \$8,228 per ton (\$3.732 per pound).

#### **Foreign Trade**

U.S. net import reliance as a percentage of apparent consumption was 59% in 1996—essentially the same percentage as in 1995. Imports accounted for 99% of primary supply in 1996, if Government stockpile sales are excluded. Canada, as usual, supplied most of the imported material. The second largest source was Norway, which has limited mine production and a single refinery—Falconbridge's Nikkelverk operation at Kristiansand. The Norwegian refinery uses Canadian and Botswanan mattes as its principal feedstocks.

Since 1992, Russia also has become an important source of nickel for the United States. U.S. imports of Russian cathode (including pellets) declined 46% in 1996, after jumping by almost a factor of 7 between 1994 and 1995. In 1996, the United States imported 17,221 tons of cathode and 734 tons of powder and/or flake directly from Russia. Importers also brought in 418 tons of Russian nickel contained in ferronickel and 4 tons contained in nickel sulfate.

In 1996, limited cutbacks in stainless steel production in North America and Western Europe caused prices for primary nickel and nickel-bearing scrap to fall worldwide. Because of the cutbacks in Europe and the declining price for primary nickel, U.S. exports of stainless steel scrap dropped 18% between 1995 and 1996. The bulk of the scrap went to meltshops in the Republic of Korea (26% of the total tonnage for 1996), Spain (21%), Canada (18%), and Taiwan (14%). The exported scrap contained an estimated 22,754 tons of nickel, down from 27,613 tons in 1995. These last figures are based on the assumption that stainless scrap has been averaging 7.5% nickel since 1989, when the changeover to the Harmonized Tariff System took effect. In recent years, U.S. exporters have had to compete against growing sales of Russian scrap to Western Europe and Japan.

At the beginning of each calendar year, the Bureau of the Census makes numerous changes to the U.S. foreign trade classification system in order to keep the system current in an evolving global marketplace. These changes, which usually affect both the Harmonized Tariff Schedule of the United States (Imports) and Schedule B (Exports), follow guidelines issued by the World Customs Organization in Brussels and the U.S. International Trade Commission in Washington, DC. In 1996, several changes were made to Chapter 75 of the tariff schedule: "Nickel and Articles Thereof." All of these changes affected HTSUSA heading 7508: "Other Articles of Nickel." A new subheading—7508.10.0000—was created for "Cloth, grill, and netting of nickel wire." The existing category for "Stranded wire" (previously 7508.00.1000) was assigned a new heading of 7508.90.1000.

#### **World Review**

Australia.—WMC Limited continued to set new production records at its operations in Western Australia. In fiscal year ending June 30, 1997, the company produced 104,667 tons of nickel in concentrate—breaking all previous records for the fifth consecutive year (WMC Limited, 1997). The new Mount Keith Mine northwest of Leinster was in its second year of operation and accounted for 35% of the total output, making it one of the larger metal mines in Australia. The Mount Keith concentrator treated 9.95 million tons of ore grading 0.60% nickel during the 12-month period, recovering 36,700 tons of nickel contained in concentrate. The concentrate was being dried at Leinster and then shipped either to WMC's smelter at Kalgoorlie or the Harjayalta smelter of Outokumpu Oy in Finland.

During the same 12-month period, WMC's other two mining operations—Kambalda and Leinster—produced 30,368 tons and 37,599 tons of nickel in concentrate, respectively. The recently expanded smelter at Kalgoorlie produced 72,939 tons of nickel in matte, but was still handicapped by air quality control restrictions. A new A\$168 million acid recovery plant commissioned in July 1996 should reduce future sulfur dioxide emissions by 90%, permitting the smelter to operate at full capacity. WMC's nickel refinery at Kwinana produced a record 47,577 tons of metal in FY 1996-97, up 2% from 1995-96.

The Forrestania Mine near Varley, Western Australia, produced 9,500 tons of nickel in concentrates in calendar year 1996, compared with 7,600 tons in 1995. The mining operation

excavated 700,000 tons of ore averaging 1.8% nickel. The mine has 500,000 tons of proven reserves and an additional 600,000 tons of probable reserves (Outokumpu Oy, 1997). The open pit mine has been in operation since 1992 and is owned by Outokumpu Mining Australia Pty. Ltd., a wholly owned subsidiary of Outokumpu Base Metals Oy and its parent, Outokumpu Oy of Finland. Outokumpu Mining Australia has three other projects under development in Western Australia: Silver Swan, Cygnet, and Black Swan. All three are 50-50 joint ventures with Mining Project Investors Pty. Ltd. (MPI) of Australia. Because Outokumpu Oy also owns 34% of MPI, it effectively has a 67% equity in each of the three projects. Mining was scheduled to begin at the Silver Swan in mid-1997 and is expected to continue for at least 5 years. The new underground mine has 640,000 tons of probable reserves with an exceptionally high grade of 9.5% nickel (Outokumpu Oy, 1997). The Silver Swan is expected to produce 12,000 tons of nickel in concentrates annually, all of which will go to the Harjavalta smelter in Finland. Outokumpu also has a 35% interest in the Honeymoon Well deposit south of Wiluna, near Lake Way and Mount Keith. The other 65% is held by the giant Rio Tinto Limited Group.

Several other mining projects were in various stages of development in Western Australia. In May 1996, Anaconda Nickel Limited completed its feasibility study of the Murrin Murrin laterite deposit, 55 kilometers east of Leonora, and decided to go ahead with the project. In October, Glencore International AG of Switzerland increased its stake in Anaconda from 14.53% to 19.99%—just below Australia's 20% threshold for regulating investments. A few weeks later, Glencore agreed to pay \$220 million for a 40% interest in the Murrin Murrin project, assuring initial financing of the mine. According to Anaconda officials, infill drilling now indicates that the deposit has at least 128 million tons of ore grading 1.01% nickel and 0.064% cobalt (Anaconda Nickel Limited, 1997).

A pressure acid-leaching plant was to be built on-site to extract the nickel and cobalt directly from the lateritic ore. The extraction process would be similar to the one used at the Moa plant in Cuba, producing a mixed sulfide precipitate containing about 55% nickel and 4% cobalt. The nickel-cobalt precipitate would then be redissolved, allowing the two metal ions to be separated from one another by solvent extraction. After separation, the nickel—now dissolved in an ammoniacal solution—would be fed into an autoclave and reduced to a metal powder in a hydrogen atmosphere.

Construction of the open pit mine and pressure acid leach plant was expected to cost A\$900 million, or about US\$655 million. Fluor Daniel Australia Ltd. was responsible for the overall design and engineering. Sherritt International was supplying the technology for hydrometallurgically extracting the nickel and cobalt. Development was to be carried out in two stages, with commissioning scheduled for the fourth quarter of 1998. At the end of the first stage, the proposed plant would be able to process about 3.75 million tons of ore per year, producing 31,500 tons per year of nickel in briquets, 13,500 tons per year of nickel in concentrate, and 3,500 tons per year of

cobalt. The second stage would raise the capacity of the operation to 75,000 tons of nickel and 4,500 tons of cobalt. As of June 30, 1997, Stage 1 of the project was 24% complete.

The Goldfields natural gas pipeline was completed in late 1996. The 1,380-kilometer-long pipeline carries gas from offshore fields in the Canarvon Basin on the North West Shelf to iron ore operations in the Pilbara and then on to nickel and gold operations as far south as Kalgoorlie. Gas began arriving at Mount Keith and Leinster in August and at Kambalda and Kalgoorlie in September. The cheaper energy provided by the pipeline was expected to spur development of Bulong, Cawse, and several other nickel laterite deposits along its route. Construction of the pipeline was financed by the Goldfields Gas Transmission Joint Venture. The venture is jointly owned by WMC (62.7% equity), BHP Minerals Pty. Ltd. (11.8%), and Normandy Poseidon Ltd. (25.5%). Boral Energy, one of the gas suppliers using the pipeline, has agreed to supply gas on a daily basis to Murrin Murrin. Boral Energy will build, own and operate an 80-kilometer spur line from Leonora to Anaconda's new extraction and refining facilities.

Canada.—Initial steps taken to develop the Voisey's Bay deposit have already begun to affect the future of both Labrador and Newfoundland. The deposit is the most important base metal discovery in Canada in more than 30 years. In 1996, new exploration data revealed that the nickel-copper-cobalt mineralization was more extensive than originally thought. The principal ore minerals are pentlandite, chalcopyrite, and pyrrhotite. As more and more drill holes intersected ore in the massive sulfide deposit, it became apparent that Voisey's Bay may prove to be one of the lower-cost sources of nickel in the world. The remote deposit is 35 kilometers southwest of the town of Nain and only 10 kilometers from a natural deep-water harbor that opens into the Labrador Sea. The harbor, at Edward's Cove on Anaktalak Bay, was to be the site of the concentrate shipping docks, a fuel storage facility, and one of two base camps.

The Voisey's Bay deposit was discovered in 1993 by two partners in a small exploration company while prospecting for diamonds as well as sulfides. In late 1994, geophysical surveying delineated a strongly conductive anomaly in the vicinity of the original discovery site—a large iron-stained hill of gossan (i.e., the oxidized capping of a ferruginous sulfide deposit). Four holes were drilled into the anomaly, one of which intercepted 33 meters of massive sulfides. Since then, airborne geophysical surveys have been conducted over 1,800 square kilometers of claims staked in the vicinity of the discovery site. Followup geophysical surveying revealed that the anomaly associated with the site widens to the east, where it takes on an ovoid shape. In January 1995, crews began drilling the ovoid feature and again intercepted massive sulfide. mineralization at this point lies immediately below the overburden, permitting open pit mining. The second drill hole (VB-95-07) to test the feature penetrated 104 meters of massive sulfide grading 3.93% nickel, 2.84% copper, and 0.14% cobalt.

More than 340 holes have been drilled on the property since 1994 and several high-priority targets still have not been evaluated. By mid-1996, three separate zones had been identified: the Ovoid, the Eastern Deeps, and the Western Extension (Voisey's Bay Nickel Company Limited, 1996b). The three zones are associated with the Reid Brook Intrusion and, in plan view, are aligned over a distance of almost 6 kilometers. The Ovoid is in the middle. The Ovoid zone has an estimated 31.7 million tons of ore averaging 2.83% nickel, 1.68% copper, and 0.12% cobalt—all of which is amenable to open pit mining. The Ovoid ore body has a wine-glass shape in section and is roughly 450 meters in length. In plan view, it is 300 meters wide at its thickest point. Preliminary drilling of the Eastern Deeps zone along a 1-kilometer traverse identified an additional 50 million tons of resources at depth averaging 1.36% nickel, 0.67% copper, and 0.09% cobalt. Subsequent drilling results suggest that this second zone may actually contain over 100 million tons of resources. Limited drilling also delineated a zone of high grade mineralization in the Western Extension that contains some 20 million tons of resources, but much more work was needed before this third resource could be satisfactorily estimated (Inco Limited, 1997b).

In late 1996, drilling crews identified a fourth zone of mineralization, 2 kilometers west of the Ovoid. This fourth zone lies beneath, and is partly contiguous with the shallower zone of the Western Extension. The newly discovered zone is in the shape of a flattened cylinder that plunges to the east towards the Ovoid. The mineralization lies 250 to 600 meters below the surface, extending over a strike length of at least 500 meters. Drill hole assays from the core of the fourth zone range from 1.2% to 2.8% nickel, indicating that the mineralization is richer than the disseminated sulfide resource found in the Eastern Deeps (Inco Limited, 1997b).

Falconbridge Limited and Inco quickly realized the significance of the Voisey's Bay discovery. Each took steps to acquire the deposit from the original owner, Diamond Fields Resources Inc. The Voisey's Bay Nickel Company Limited, a subsidiary of Diamond Fields at the time, held exploration and development rights to the deposit along with rights to 2,000 square kilometers of other land in Labrador. In June 1995, Inco acquired 7% of Diamond Fields' common stock for \$111 million. At the same time, Inco also acquired a 25% interest in the deposit itself as part of a related but separate transaction with Diamond Fields. This second transaction cost Inco \$387 million in preferred stock and \$18 million in cash. Inco also acquired 2 million common shares of Diamond Fields from three private shareholders. The three shareholders received a total of 1.4 million shares of Inco common stock and \$68 million in cash. The various agreements gave Inco roughly a 30% interest in the immense deposit. Inco was to be responsible for marketing all of the nickel and cobalt under a long-term agreement.

In late 1995, Falconbridge approached Diamond Fields and offered to acquire the 75% of Voisey's Bay Nickel not held by Inco. Under the terms of the proposal, Diamond Fields would have merged with Falconbridge. Diamond Fields shareholders were to have received Falconbridge stock and corporate notes plus a limited amount of cash in exchange for their common

share holdings. However, under the terms of the June 1995 agreement with Diamond Fields, Inco had the right to submit a counterproposal. Inco's management immediately began evaluating a variety of possible responses and postponed commenting on the matter for 3 months. On February 9, 1996, the board of directors of Diamond Fields unanimously approved Falconbridge's merger proposal, putting pressure on Inco to make a decision. Falconbridge's offer indicated that discovery of the Voisey's Bay deposit had transformed Diamond Fields into a company worth at least \$4 billion.

Following brief, intense negotiations, Inco made a counteroffer directly to Diamond Fields' board of directors. The counteroffer was made public on March 26, 1996. Inco would acquire all of the common shares of Diamond Fields that were not already owned by Inco. In exchange, Diamond Fields shareholders would receive cash, Inco common shares, and two types of Inco preferred stock. At the time, financial experts estimated Inco's counteroffer to be worth about \$3.5 billion. On April 3, Diamond Fields' board of directors provisionally accepted Inco's counteroffer and submitted it to their shareholders for approval (Heinzl, 1996). At that point, Falconbridge withdrew from the bidding. Both the shareholders of Inco and Diamonds Fields approved Inco's proposal.

On August 21, Inco completed its acquisition of Diamond Fields, giving it control of the Voisey's Bay deposit. The settlement formalized the provisional agreement reached with Diamond Fields' management on April 3. Inco's accountants valued the stock exchange and cash settlement at \$3.093 billion (Inco Limited, 1997a). Two days after settlement, Inco set up a special executive team to oversee development of the Voisey's Bay deposit and the construction of related processing facilities in the Province of Newfoundland and Labrador. The sevenmember team was based in St. John's, Newfoundland. The Labrador operation remained under control of Voisey's Bay Nickel, which was converted into a wholly owned subsidiary of Inco. Under the terms of the settlement, Inco can sell—without restrictions—up to 24% of Voisey's Bay Nickel if need be. Inco also took over control of Diamond Fields' exploration properties in Greenland and Norway. In September, Inco filed for environmental permitting of the proposed mine and mill complex at Voisey's Bay. If everything proceeds according to the current schedule, production of concentrate could begin in late 2000.

On November 29, 1996, Voisey's Bay Nickel announced that it was planning to build a major smelting and refining complex at Argentia on the island of Newfoundland (Brockelbank, 1996a; Voisey's Bay Nickel Company Limited, 1996a). The complex would process all of the nickel-cobalt concentrate produced at Voisey's Bay. (See Current Research and Technology.) Argentia was chosen over a number of other sites on the island and in Labrador. The proposed site is on the north side of a former U.S. naval base, about 130 kilometers west of St. John's. The Argentia complex would cover about 2 square kilometers (500 acres) and could be in full production as early as 2001. When fully operational, the complex would be able to process 816,000 tons per year of sulfide concentrate and

produce 122,000 tons per year of refined nickel and 3,000 tons of cobalt, making it the largest nickel operation outside of Russia. It also would be somewhat larger than Inco's operation at Sudbury, Ontario, which is rated at about 100,000 tons per year of nickel in smelter products. About 16,000 tons per year of copper would be produced at Argentia as a byproduct from the nickel-cobalt concentrate.

The mill at Voisey's Bay also would produce a separate predominately chalcopyrite (i.e., copper-rich) concentrate. This second sulfide concentrate, representing about 80% of the copper in the ore, would be processed elsewhere for economic reasons. A viable, dedicated copper smelting and refining operation would require considerable more copper concentrate than that projected from Voisey's Bay. The mill would produce about 75,000 tons per year of copper in chalcopyrite concentrate.

Argentia is on tidewater and close to some major North Atlantic shipping lanes, permitting Voisey's Bay Nickel to economically supplement its feedstocks with nickel concentrates purchased on the world market. The site also is relatively close to inferred resources of nickel sulfides being evaluated in the Lac Manitou, Sept-Îles, and Gaspé regions of southeastern Quebec as well as in parts of Maine. All four regions could conceivably supply additional nickel concentrate for the smelter.

The Voisey's Bay discovery has spurred nickel exploration throughout Eastern Canada and heightened expections of a number of small exploration companies. In August 1996, a team of geologists employed by the Provincial Government of Quebec encountered two gossans while mapping part of the Lac Manitou-Lac Nipisso area. The discovery was made near Lac Volant, a smaller lake east of Lac Nipisso. Lac Volant is about 60 kilometers northeast of the iron ore port of Sept-Îles and lies within the Grenville structural province of the Precambrian Canadian Shield. As soon as officials of the Quebec Government learned of the find, they temporarily withdrew 800 square kilometers of land surrounding the gossans from staking. Government geologists have since staked more than 130 claims for the Crown within the withdrawn parcel. St. Geneviève Resources Ltd. and Virginia Gold Mines Inc., already exploring in the area, quickly staked more than 1,000 claims around the perimeter of the withdrawn area. Surface samples from a number of these claims showed enrichment of copper, nickel, and cobalt.

On October 9, the Quebec Government lifted its ban, triggering a staking rush along the entire North Shore of the St. Lawrence estuary. Other companies currently exploring the North Shore include Azimut Exploration Inc., Falconbridge Limited, Fancamp Resources Limited, GeoNova Explorations Inc., Inco Limited., Kennecott Canada Inc., and Vior Mining Exploration Co. Inc. (Brockelbank, 1996b). The drilling results to date have been disappointing. If the Lac Manitou area should turn out to be a significant resource of nickel, sulfide concentrates could be shipped relatively easily across the Gulf of St. Lawrence to Argentia. Lac Volant is only about 15 kilometers from the Quebec North Shore and Labrador Railway, which operates between Sept-Îles and the iron mines near

Labrador City.

Falconbridge continued moving forward on its Raglan Project in the Nunavik territory of northern Quebec. The development of the mine and concentrator at Katinniq was slightly ahead of schedule. Most of the buildings were in place and all of the road and site preparation has been completed. About 450 people were working at the site. The mill modules were being constructed in Quebec City and were to be transported to Katinniq in mid-1997. Mining was to begin in December 1997, with the first shipment of concentrate due to leave Deception Bay in early 1998 (Falconbridge Limited, 1997). The concentrate would be shipped by sea to Quebec City and then railed to the company's smelter at Sudbury. Falconbridge had been planning to produce 20,000 tons per year of nickel in concentrate over the first 15 years of operation. However, recent drilling has identified three new zones of mineralization, adding 1.3 million tons of resources to Raglan's ore reserves. According to Falconbridge officials, the Raglan deposit now has 20.6 million tons of proven or possible reserves (Falconbridge Limited, 1997). Of the 20.6 million tons, 14.4 million are proven or probable, averaging 3.17% nickel and 0.88% copper. The additional reserves may permit Falconbridge to increase Raglan's capacity in the future to 30,000 tons per year of nickel.

In the Sudbury Basin of Ontario, Falconbridge was in the process of bringing its previously idled Lockerby Mine into full production. In 1996, the mine produced 92,000 tons of ore averaging 2.27% nickel and 1.19% copper—containing some 2,100 tons of nickel and 1,100 tons of copper. By 1998, production should reach 8,000 tons of contained nickel and 3,500 tons of contained copper. Falconbridge had four other nickel-copper mines operating along the rim of the Basin—the largest being the Onaping/Craig complex. Underground exploration drilling at Onaping/Craig since 1995 has identified significant additional sulfide mineralization. Falconbridge's five mines in the basin extracted a total of 2.81 million tons of ore averaging 1.77% nickel and 1.93% copper. The company's smelter at Falconbridge recovered 45,709 tons of nickel and 17,552 tons of copper in matte made from the mined ores and custom feed.

Inco's new McCreedy East Mine at Sudbury came on-line in 1996 and should be in full production by 1999. McCreedy East is one of the company's lower-cost mines in Canada and, when fully operational, will have an annual production capacity of 11,000 tons of contained nickel and 28,000 tons of contained copper. At the end of 1996, Inco's Victor Deep exploration shaft on the northeastern edge of the basin was close to its planned depth of 1,460 meters. Underground exploration drilling outward from levels near the bottom of the shaft was to begin in 1997.

In Manitoba, Inco continued to deepen its Birchtree Mine and fully develop its 1-D ore body. At yearend 1996, Inco's Canadian mines had 364 million tons of ore reserves. The reserves contained 5.66 million tons of nickel and 3.72 million tons of copper, which equated to an average grade of 1.56% nickel and 1.02% copper (Inco Limited, 1997a). The total does

not include additional resources associated with the Voisey's Bay deposit in Labrador, the Victor Deep deposit near Sudbury, and recent discoveries in the Pipe area of Manitoba.

Colombia. - In June 1996, the Government of Colombia announced that it would sell its 47.69% interest in Cerro Matoso S.A. (CMSA). CMSA operates an open pit laterite mine and smelter near Montelibano in the Department of Cordoba. The Government had been planning to privatize CMSA for some time and finally decided in September to sell almost of its holdings to its partner, Gencor Limited of South Africa. The sale, which was completed in February 1997, increased Gencor's equity in the ferronickel producer from 52.31% to 98.88%. The remaining 1.12% of the shares was held by CMSA employees, together with employee unions. Gencor paid the Government of Colombia 178 billion pesoes, or about \$166 million, for its holdings (Billiton Plc., 1997). CMSA is currently paying the Government a royalty of 8% of the gross value of the ferronickel extracted less processing costs. The royalty was to rise to 12% in the year 2007. As part of the sales agreement, CMSA gained rights to exploit the concession until 2026 and has an option to extend these rights to 2041.

In 1996, the Cerro Matoso smelter produced 22,934 tons of nickel contained in ferronickel bars and granules, down 7% from the record 24,565 tons set in 1995. The nickel content of the ferronickel ranged from 39% to 43%. The company exported 23,482 tons on a contained basis in 1996, 94% of which went to Europe. The remaining 6% was shipped to the United States. Electricity accounted for approximately 28% of the company's cash production costs in 1996. In April, CMSA entered into a 5-year agreement with Corporación Eléctrica de la Costa Atlántica, the state-owned electricity supplier. As of June 30, 1996, CMSA had 31.3 million tons of proved ore reserves averaging 2.5% nickel and 14.1 million tons of probable reserves averaging 2.2% nickel (Billiton Plc., 1997).

Côte d'Ivoire.—Falconbridge Limited has been evaluating several laterite deposits northeast of Mount Nimba where the borders of Côte d'Ivoire, Guinea, and Liberia intersect. The project is part of a joint venture with Trillion Resources Ltd. of Kanata, Ontario, and the Société d'État pour le Développement Minier de la Côte d'Ivoire. To date, much of the work has focused on pyroxenites in the highlands region between Biankouma and Touba, northwest of Man. Resources have been identified at three locations. At the end of 1995, the Foungouesso-Moyango area, 24 kilometers north of Biankouma, had 39.5 million tons of material, averaging 2.00% nickel, while the Viala-Yamatoulo-Touba area had 18.7 million tons averaging 1.77% nickel. The Sipilou North area had 54.0 million tons grading 1.80% nickel and 0.10% cobalt (Falconbridge Limited, 1996). Additional material was identified during the 1996 drilling program, increasing total known resources to 226.3 million tons with an average grade of 1.50% nickel and 0.10% cobalt (Falconbridge Limited, 1997).

Falconbridge launched the third phase of its drilling program in October 1996 and, at yearend, had a hydrometallurgical scoping/pre-feasibility study in progress. A miniscale pilot plant was being set up to process bulk samples. Earlier

metallurgical tests had indicated that ferronickel could be made from the Biankouma-Touba laterites using the Falcondo process presently employed in the Dominican Republic. However, hydrometallurgical extraction is apparently proving to be more suitable and cost effective than pyrometallurgical extraction in this particular situation. Satisfactory completion of the exploration program should earn Falconbridge a 60% interest in the Biankouma-Touba project (Trillion Resources Ltd., 1997). In December, Falconbridge signed a memorandum of understanding with the Government of the Côte d'Ivoire that outlined a schedule for further project work and specified key downstream decision points if development proves economically feasible (Falconbridge Limited, 1997).

Cuba.—Metals Enterprise continued to modernize the Moa mining and mineral processing facility in Holguín Province. The vertically integrated enterprise is a 50-50 joint venture between General Nickel of Ciudad Habana and Sherritt International Corp. of Toronto, Canada. Cuba's other nickel processing plants—Nicaro and Punta Gorda—are not part of the joint venture. In 1996, the Moa facility produced 26,034 tons of nickel and cobalt contained in mixed sulfides, more than double the 12,549 tons reported for 1994 when the joint venture was formed (Sherritt International Corporation, 1997). The sulfide precipitate was being shipped from Moa Bay via Halifax, Nova Scotia, to the joint venture's nickel-cobalt refinery at Fort Saskatchewan, Alberta. In 1996, the Fort Saskatchewan refinery produced 25,300 tons of nickel in metal powder and briquets together with 2,100 tons of refined cobalt. This was the highest output in the refinery's 43-year history.

Metals Enterprise will spend approximately \$165 million rehabilitating and upgrading the Moa facilities over the next 3 years. By 1999, the Moa facility should be able to produce 27,000 tons of contained nickel plus cobalt per year. A pressurized leach process is used to extract the two metals from the goethite ore. The process is relatively efficient, recovering more than 90% of the nickel, but consumes large amounts of sulfuric acid. Almost one-third of the modernization money was being used to replace the three existing acid plants with a single modern unit capable of producing 1,500 tons of acid per day. One of the three plants was permanently closed in September 1995 because of high maintenance costs, but the other two have been refurbished in the interim. Overhaul of one plant was completed in 1996; the second, in early 1997. Supplemental acid was being purchased on the open market.

WMC and Commerical Caribbean Nickel S.A. were in the final stages of formalizing their joint venture to evaluate and, if feasible, develop the Pinares de Mayari West lateritic deposit. In January 1996, WMC signed a Heads of Agreement with the Cuban parastatal, but a number of details of the joint venture still had to be worked out. The Pinares deposit is located in Holguín Province and reportedly contains more than 200 million tons of ore exceeding 1% nickel and 0.1% cobalt (WMC Limited, 1997). The feasibility work will take several years to complete. WMC's legal advisors believe that the greenfield project falls outside the purview of "The Cuban Liberty and Democratic Solidarity Act" (i.e., the Helms-Burton Act).

Dominican Republic.—Falconbridge Dominicana, C. por A., (Falcondo) produced 30,376 tons of nickel in ferronickel, down slightly from the 30,886 tons reported for 1995. More than 90% of the ferronickel was in the form of ferrocones, a product resembling a large metallic gumdrop and weighing about 125 grams. The tonnage of lateritic ore delivered to the processing plant in 1996 was the second highest in the history of the Bonao Mine, but the average grade of the ore was only 1.32% nickel—the lowest on record (Falconbridge Dominicana, C. por A., 1997).

Over the last few years, the grade of the laterite mined at Bonao has gradually declined. To counter the dropoff in nickel content, Falcondo has begun developing an improved circuit for upgrading the laterite prior to reduction in the electric arc furance. The process, which grinds the ore more finely, is still at the pilot-plant stage but could increase annual production by 4,000 tons of nickel in ferronickel, while simultaneously lowering operating costs. If successful, the cutoff grade for the mine could be lowered from 1.2% nickel to 1.0%, increasing ore reserves by more than 60% and extending the life of the mine from 21 to 33 years (Falconbridge Limited, 1997).

European Union.—Finland.—In 1995, Outokumpu Base Metals Oy completed a major expansion of its Harjavalta smelter and refinery in Turku-Pori Province, Finland. The expansion raised the production capacity of the complex to 32,000 tons per year of nickel briquets and cathode and 160,000 tons per year of blister copper. In 1996, parts of the smelter and refinery were still in a startup mode and experiencing operational problems related to the expansion (Outokumpu Oy, 1997). Despite these problems, Harjavalta produced 29,300 tons of nickel and 150,300 tons of blister copper—a dramatic increase in comparison to 1995 when interruptions linked to the expansion caused output to drop to 18,400 tons of nickel and 88,300 tons of copper. Plans have already been drawn up to increase the annual production capacity of the smelter to 40,000 tons of nickel. In the fall of 1996, the LME registered Outokumpu's new nickel briquets, permitting them to move freely in the global marketplace.

Outokumpu Base Metals has only one nickel mine still operating in Finland—the Hitura Mine near Ainastalo. Because of declining ore reserves, the Vammala Mine was closed in January 1995. Since March 1995, the Harjavalta smelter has relied mainly on concentrates from WMC's new Mount Keith Mine and Outokumpu's own Forrestania Mine, both in Western Australia. In 1996, the Hitura Mine produced 3,100 tons of nickel in concentrate, the same tonnage as in 1995. According to company records, at the end of 1996, the Hitura Mine had 0.6 million tons of proven and probable reserves, averaging 0.7% nickel (Outokumpu Oy, 1997). The mine had an additional 6.1 million tons of measured, indicated, and inferred resources containing 0.8% to 0.9% nickel.

*Indonesia.*—P.T. International Nickel Indonesia (P.T. Inco) was in the midst of a major expansion of its mining and smelting complex on the island of Sulawesi. The \$580 million expansion will take 3 more years to complete and raise the production capacity of the Soroako smelter from 45,000 tons per year of

nickel in matte to 68,000 tons per year. P.T. Inco officials approved the expansion after the Government of Indonesia agreed to modify the company's Contract of Work and extend the contract to the year 2025. The original contract, signed in 1968, was due to expire in 2008. The new agreement was formally signed in Jakarta on January 15, 1996. The bulk of the additional production was expected to be consumed in Asia—reportedly the fastest growing market for nickel at the present time (Upton, 1997).

P.T. Inco produced 39,503 tons of nickel in matte in 1996, down 13% from the record high 45,463 tons of 1995. Production was interrupted on September 10 when one of the three electric arc furnaces at Soroako was damaged in an eruption. The furnace had to be rebuilt and did not come back on-line until December.

The matte, which averaged 78% nickel, was being shipped to Tokyo Nickel Company, Ltd. at Matsuzaka, Japan, for conversion into oxide sinter and utility nickel. The refining capacity of the Matsuzaka facility was being expanded by 50% to handle the additional output from Soroako. By late 1998, the Matsuzaka facility should be able to process 54,000 tons per year of nickel (Inco Limited, 1997a). Inco Limited, which owns 59% of P.T. Inco, also has a 51% interest in Tokyo Nickel.

On August 7, 1996, BHP Minerals Limited of Australia and P.T. Aneka Tambang of Indonesia formed a joint venture to evaluate lateritic nickel prospects on Gag Island, Irian Jaya (BHP Minerals Limited, 1996). Gag Island is about 130 kilometers southeast of Halmahera, Maluku and 150 kilometers northwest of Sorong at the northwestern tip of Irian Jaya. The nickel prospects on Gag Island have been known for some time and are currently held by Aneka Tambang. Aneka Tambang is a state-owned mining enterprise. The joint venture is hoping that advanced recovery technologies developed by BHP will make the Gag project economically feasible.

Gag Island is only 40 kilometers southeast of Gebe Island, Maluku, where Aneka Tambang has one of its two principal nickel mines. The other mine is near the company's ferronickel smelter at Pomalaa in southeastern Sulawesi. The Gebe Island Mine has been in operation since April 1979 and is currently shipping ore to Pomalaa, QNI Ltd.'s Yabulu Refinery in Queensland, Australia, and Japanese ferronickel producers. The open pit mine has 27 million tons of reserves averaging 2.2% nickel (BHP Minerals Limited, 1996).

BHP has a 75% interest in the Gag Island venture and has already submitted a Contract of Work to the Government of Indonesia. The initial feasibility study should be completed by January 1999. The Government of Indonesia is considering partially privatizing Aneka Tambang. A portion of the funds from the stock flotation would be used to expand the Pomalaa smelter. In 1996, the smelter produced 9,397 tons of nickel in ferronickel, down from 10,733 tons in 1995.

*New Caledonia.*—Société Métallurgique Le Nickel (SLN) operated three nickel mines on the island in 1996—Thio, Kouaoua, and Népoui-Kopéto. A fourth mine, Etoile du Nord (also known as Kaala-Gomen), was being operated by contractors. SLN mined 2.40 million tons of lateritic ore,

slightly more than in 1995. The company also purchased 562,000 tons of ore from contractors working deposits owned by SLN. The bulk of the ore was screened at the individual mine sites and then shipped to the company's Doniambo metallurgical complex outside the capital of Nouméa (Eramet Group, 1997).

At Doniambo, the ores from the four 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 produces ferronickel containing 29% nickel and nickel matte that assays about 75% nickel. The matte is sent to the Sandouville-Le Havre refinery in northern France for conversion into cathode. The Sandouville refinery is owned by the Eramet Group, SLN's parent company. In 1996, the Doniambo smelter produced 42,173 tons of nickel in ferronickel and 11,239 tons of nickel in matte. The combined output of 53,412 tons was an all-time high for Doniambo, edging out 1995's record breaking 52,343 tons.

SLN accounted for 42% of New Caledonian mine production in 1996. The other 58% of mine production was divided between Société Minière du Sud Pacifique (SMSP), J.C. Berton Mines, Nickel Mining Corp., Société des Mines de la Tontouta, and several other independent mining companies. The overseas territory exported 69,358 tons of nickel in ore. The 69,358 tons of nickel included 34,795 tons in garnerite shipped to Japan; 15,248 tons in garnerite shipped to the United States; and 19,315 tons in limonitic laterites shipped to Australia.

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 55,000 tons of nickel in ferronickel and use local lateritic ores as feedstock (du Luart, 1997; Falconbridge Limited, 1997). The two companies have already prepared a scoping study and presented it to the governments of France and the territory. The ferronickel project was being supported by the Kanak Socialist National Liberation Front, a proindependence movement, which is especially strong in that part of the island (Buchan, 1997b). The Kanak Front has been told that the mining and smelting complex would employ 700 islanders and lead to the indirect However, to be employment of an additional 2,000. economically viable, the project requires a minimum of 25 years of ore reserves. These reserves exist, but many of the better deposits near the proposed plant site are already controlled by SLN, the principal mine operator on the island. There are three key deposits in the vicinity of the proposed plant: Tiébaghi, Poum, and Art. Together they have an estimated 1.6 million tons of nickel in garnierite reserves averaging 2.5% nickel (Eramet Group, 1997).

Eramet was being pressured to surrender key mining reserves in the Northern Province considered vital to the future viability of SLN (Eramet Group, 1997; Buchan, 1997a). Initially, SLN was asked to cede its new Tiébaghi Mine being developed at the northwestern tip of the island. Mining at Tiébaghi was scheduled to start in the second half of 1997. Eramet countered with a proposal calling for SMSP to cut back on its ore exports and, instead, use part of its mine production as

feed for the proposed plant. SLN and the island's other mine operators would make up any shortages in feedstocks. Supported by the Government of France, SMSP then proposed to swap its Poum Mine for SLN's Koniambo deposit. The Koniambo deposit is roughly midway between Kaala-Gomen and Népoui-Kopéto and has much larger reserves than Poum. On December 17, Eramet's board of directors agreed in principle to the swap if adequate financial compensation was made to SLN. Negotiations stalled shortly afterwards. At yearend, the Government of France was considering buying or, as a last resort, expropriating the Koniambo deposit and turning it over to SMSP and Falconbridge. Eramet had not planned to mine the deposit until the year 2010.

The Government of France is the largest shareholder in Eramet, with an interest of 55%. The minority shareholders, which include several mutual funds and pension funds based in the United States and the United Kingdom, were strongly opposed to any type of expropriation. The Government was also considering paying Eramet some \$300 million for the loss of Koniambo. If the concessions issue can be settled, construction of the SMSP-Falconbridge plant could begin as early as 1999, with production commencing in the year 2003 and continuing thru 2028.

The Kanak Front, the local trade unions, and the Government of France all would prefer to have more ore processed on the island and less exported. At yearend, the trade unions were threatening to block ore shipments in support of the proposed ferronickel plant. The citizens of New Caledonia are to vote on self-determination in a referendum sometime in 1998.

In July 1995, Inco initiated a feasibility study of its Goro holdings at the southeastern tip of the island. Drilling to date has delineated a resource of 150 million tons of lateritic material grading 1.6% nickel and 0.16% cobalt (Inco Limited, 1997e). The feasibility study was being sponsored by Goro Nickel S.A., a joint venture between Inco [85% interest] and France's Bureau de Recherches Géologiques et Minières (BRGM) [15%]. The nickel and cobalt would be recovered using a pressure acid leaching process combined with solvent extraction. The feasibility study was scheduled to be completed in late 1997.

Norway.—Falconbridge Nikkelverk A/S produced 61,584 tons of refined nickel, up 16% from 53,238 tons in 1995 (Falconbridge Limited, 1997). The jump was made possible by increased shipments of matte from both Falconbridge's smelter at Sudbury and BCL Ltd.'s smelter at Selebi Phikwe in Botswana. The Nikkelverk refinery at Kristiansand was capable of producing 69,000 tons per year, but suffered from a shortage of matte in 1995. The refinery, which was just upgraded in 1994, was being expanded again—this time to accommodate the matte scheduled to be made from Raglan's concentrates. When the expansion is completed in early 1998, the Nikkelverk complex will have an annual capacity of 85,000 tons of refined nickel metal and 3,700 tons of refined cobalt.

In December 1995, Outokumpu Base Metals Oy acquired a 70% interest in Nikkel og Olivin A/S. The remaining 30% was held by Nordlandsbanken AS, a Norwegian Bank. Nikkel og

Olivin mines nickel sulfides at Ballangen, about 30 kilometers southwest of the iron ore port of Narvik in Nordland. In 1996, the entire annual output of the underground mine—some 4,000 tons of nickel in concentrate—went to the Harjavalta smelter in Finland.

Russia.—The Russian Federation produced 190,000 tons of nickel, about 5% less than in 1995. RAO Norilsk Nickel was by far the largest producer, accounting for 177,185 tons of nickel metal, along with 340,000 tons of copper metal, and 3,151 tons of cobalt in metal, oxide, or sulfate (Platt's Metals Week, 1997). Nickel production was down 2% from 1995, when the company's output was 180,100 tons. The decrease came at a time when the company was in a difficult financial situation, experiencing cash flow problems, and undergoing a change in management. The cash flow problems made it difficult for the company to meet its payroll and purchase essential supplies.

Norilsk Nickel was behind in its tax payments and, like several other companies with Arctic operations, was heavily in debt to its natural gas suppliers. The company's largest operation—the Norilsk Nickel Mining and Metallurgical Combine on the Taimyr Peninsula—was having difficulty maintaining production because of cutbacks in deliveries of natural gas. The combine's sole supplier, NorilskGazProm, was threatening to reduce deliveries by 25% if Norilsk did not pay \$173 million owed the utility. NorilskGazProm has a monopoly on natural gas in the Taimyr region, but has been rapidly depleting its reserves, forcing the utility to raise prices. The metallurgical combine is the utility's biggest customer. Development of the Peliatkinskoe gas field would have helped alleviate the depletion problem, but NorilskGazProm lacked the massive financial resources required for such a project. Norilsk Nickel also was struggling with rising transportation costs. The company owed significant sums of money to the Russian merchant fleet servicing the vital port of Dudinka.

Norilsk Nickel was partially privatized in April 1994 and has since undergone a major restructuring of its management. The Russian government still remains the principal shareholder in the joint stock company and has put Uneximbank in charge of its interests. In November 1995, Uneximbank acquired 51% of Norilsk Nickel's voting stock from the Government under a controversial loans-for-shares program. The Government gave the stock to Uneximbank as collateral in exchange for a \$170 million loan. The stock transfer was later approved by the Duma—the Russian parliament—effectively Uneximbank a 38% interest in the company. Uneximbank is one of the largest commercial banks in Russia and is based in Moscow. At yearend 1996, Uneximbank was hoping to gain official ownership rights to the giant nickel producer at a special auction that would be closed to foreign investors. The Government still considers Norilsk Nickel to be a strategic state asset. The controversial auction was scheduled for the summer of 1997. Uneximbank also was prepared to finance part of the Peliatkinskoe gas project.

Norilsk Nickel was under pressure from both foreign and domestic environmental groups to drastically reduce sulfur dioxide emissions from its three smelters. Scandinavian environmentalists have blamed the Pechenga smelter, in particular, for much of the sulfur dioxide found in the air over Lapland. The company was actively seeking loans from the Russian government to modernize all three facilities and correct the pollution problem. In 1993, Russian officials awarded a contract to a Norwegian-Swedish engineering consortium to modernize the Pechenga smelter, but a number of details in the final contract were never resolved. The consortium was composed of Elkem Technology (Oslo), Kvaerner Engineering (Oslo), and Boliden Contech AB (Stockholm). The Norwegian and Russian Governments had agreed to loan Norilsk Nickel almost one-half of the \$258 million required for the project. The Pechenga modernization project was in limbo at the end of 1996, after a key meeting scheduled for December 20 between Kvaerner and Norilsk Nickel was postponed.

Russia has three smaller producers, all in the Ural Mountains: RAO Ufaley Nickel, RAO Yuzural Nickel, and RAO Režsky Nickel. 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 166,300 tons of unwrought nickel (HTS No. 7502) in 1996. Of the 166,300 tons, 135,600 tons, or about 82%, went into LME warehouses in Rotterdam. Other signficant destinations were Germany (6%), Finland (5%), and the Republic of Korea (2%). Norilsk Nickel did not ship any matte to Falconbridge's Nikkelverk refinery in Norway in either 1995 or 1996.

In the last few years, Russia has become an important source of nickel-bearing stainless steel scrap. Most of the scrap was coming from obsolete military and industrial equipment. Several foreign stainless steel producers and scrap trading firms have set up collection operations in Russia and Ukraine.

### **Current Research and Technology**

The Sumitomo Refining Process.—Sumitomo Metal Mining Co. Ltd. of Japan has agreed in principle to license its patented matte chlorine leach electrowinning (MCLE) process to Inco. Inco wants to use the hydrometallurgical process in its proposed nickel smelting and refining complex at Argentia, Newfoundland (Inco Limited, 1997c). Feed for the Argentia complex would come by sea from Inco's new mine being developed at Voisey's Bay, Labrador.

The nickel-copper-cobalt ore mined at Voisey's Bay would be milled on-site. The Voisey's Bay mill would have a differential froth flotation circuit and produce two concentrates—one of pentlandite and one of chalcopyrite. Only the pentlandite concentrate would go to Argentia. The current plan calls for the chalcopyrite concentrate to be toll smelted elsewhere. Production of concentrate was scheduled to begin in late 1999.

At Argentia, Inco would convert the pentlandite concentrate into a pebble-sized, granulated nickel sulfide matte, using proprietary flash smelting technology developed in-house (Voisey's Bay Nickel Company Limited, 1996c). The oxygen flash smelting produces a crude iron-nickel-copper matte that has to be processed further in a converter to remove the bulk of the iron. In the converter, oxygen is blown up through the molten matte, oxidizing the iron which then enters the overlying silicate slag layer. After separation of the iron, the nickel-rich matte left in the converter—the Bessemer matte—is ready to be refined and Sumitomo's process enters into the picture.

The Bessemer matte has three principal components:  $Ni_3S_2$ , nickel-copper alloy, and  $Cu_2S$ . The MCLE process would be used to leach the nickel, copper, and cobalt from the matte, leaving behind elemental sulfur in a solid phase while simultaneously separating the copper from the nickel and cobalt. The sulfur would be drawn off, melted, filtered, and then pumped back to the smelter's sulfuric acid plant where it would be burned to sulfur dioxide and added to the off-gas feed stream from the flash furnace.

The MCLE process utilizes the cupric-cuprous redox couple to separate the nickel from the copper. The first step in the process is to grind the granulated matte and feed it as a slurry into a two-stage counter-current chlorine leach circuit. The chlorine leach solution contains cupric ion which immediately reacts with the nickel-copper sulfides in the matte. The freshly dissolved copper accelerates the leach process. A series of rapid reduction-oxidation reactions occurs, causing the nickel to dissolve out of the matte and the copper to precipitate out of the leach as a relatively insoluble cuprous sulfide cement. The cobalt is recovered from the copper-free pregnant liquor by precipitation as cobaltic hydroxide. The nickel-rich, cobalt-free chloride solution can now be fed into an electrowinning cell. During electrowinning, some of the chloride ions are oxidized and form chlorine gas. The chlorine gas is removed and recycled back to the chlorine leach circuit. The nickel is recovered as nickel metal cathode.

The cuprous sulfide cement and any undissolved nickel sulfides are bled off and fed into the main chlorine leach tank where the chlorine gas from the electrowinning cells are used to reoxidize the cuprous ion. The bulk of the dissolved copper is removed and recovered in a separate electrowinning circuit.

Sumitomo has been using the MCLE process to produce high-quality nickel metal and cobalt at its Niihama refinery in Ehime Prefecture, Japan, since 1992 (Ishikawa, 1994). The process is carried out in a closed system, making it environmentally friendly. The first refined nickel would be available from Argentia in late 2000, with full production in 2001. When fully operational, the complex will be able to process 816,000 tons per year of sulfide concentrate and produce 122,000 tons per year of refined nickel.

Sumitomo and Inco have been cooperating on projects for more than a decade. P.T. Inco's Soroako operation in Indonesia supplies much of the matte used at Niihama. In 1988, Sumitomo purchased a 20% interest in P.T. Inco from Inco Limited for \$100 million. Prior to the acquisition, P.T. Inco was owned 98% by Inco and 2% by a consortium of six Japanese companies that included Sumitomo. The current equity breakdown for P.T. Inco is: Inco, 58.7%; Sumitomo, 20.1%;

public shareholders, 20.0%; and four other Japanese companies, 1.2%. The public shares are traded on the Indonesian stock exchanges.

Nickel-Based Batteries for Electric Vehicles.—On December 5, 1996, General Motors Corp. (GM) began leasing its EV1 at dealerships in Southern California and Arizona (Akre, 1996). The EV1 is a new production vehicle rather than a conventional model modified to run on batteries. The two-passenger automobile has a 137-horsepower three-phase AC induction motor powered by a 16.8 kilowatt-hour maintenance-free lead-acid battery pack. It has a range of about 145 kilometers (90 miles) on the open highway, but only 113 kilometers (70 miles) in city traffic.

In June 1994, GM entered into a joint venture with Ovonic Battery Co., Inc. to manufacture EV batteries utilizing proprietary nickel-metal hydride technology developed by Ovonic Battery. The joint venture, GM Ovonic L.L.C., has been purchasing both negative electrodes and battery packs from Ovonic Battery. GM has a 60% interest in the joint venture; Ovonic Battery, 40%. GM Ovonic was to begin limited production of nickel-metal hydride battery packs for the EV1 in late 1997 or early 1998. The new nickel-metal hydride batteries reportedly are interchangeable with the lead batteries currently being used in the EV1, but are considerably more expensive to manufacture (Wrigley, 1997). The new nickel-metal hydride batteries are expected to increase the range of the EV1 to at least 190 kilometers (120 miles).

Solectria Corp. of Wilmington, MA, has begun selling a four-door sedan powered by Ovonic nickel-metal hydride batteries. Preliminary testing by the California Air Resources Board indicates that the Solectria has a range of 275 kilometers (170 miles) at approximately 80 kilometers per hour (50 miles per hour). Several Solectria models already have been delivered to the National Highway Traffic Safety Administration for testing to ensure that they fully comply with Federal motor vehicle safety standards.

Honda Motor Co. Ltd. of Japan, which owns 6.5% of Ovonic Battery, and Hyundai Motor Co. Ltd. of the Republic of Korea also have agreed to use Ovonic nickel-metal hydride batteries in their EV test fleets. Honda was to begin leasing its four-passenger compact EV to fleet owners in the Los Angeles and Sacramento areas of California in the spring of 1997. The vehicle, called the EV Plus, is made in Japan and has a rated range of 160 to 200 kilometers (100 to 125 miles) per charge in city traffic. The 288-volt brushless DC motor is powered by 24 12-volt sealed nickel-metal hydride batteries.

Nissan Motor Co. Ltd. was to launch a limited leasing and sales program in Japan for its Prairie Joy EV in the spring of 1997. The Prairie Joy can carry four people and is intended initially for local government and fleet users. The 1,690-kilogram EV is powered by lithium-ion batteries, developed jointly by Nissan and the Sony Corp. Lithium-ion batteries have about 1.5 times the energy density (i.e., storage capacity) of equivalent nickel-metal hydride batteries.

The Furukawa Battery Co., Ltd.—an Ovonic licensee—and Tohoku Electric Power Co., Inc. of Japan have jointly developed

a nickel-metal hydride battery that provides a 150-kilometer (93-mile) driving range per charge at a constant speed of 40 kilometers per hour (25 miles per hour). Prototype EV's powered by the 15-kilowatt-hour battery have attained a top speed of 110 kilometers per hour (68 miles per hour). Other Ovonic licensees include Energizer Power Systems (formerly Gates Energy Products and now part of the Eveready Battery Co., Inc.); Canon, Inc., Japan; Gold Peak Industries (Holdings), Ltd., Hong Kong; Hitachi Maxell, Ltd., Japan; Matsushita Battery Industrial Co., Ltd., Japan; Samsung Electronics Co., Ltd., Republic of Korea; and VARTA Batterie AG, Germany.

In France, PSA Peugeot Citroën and Renault began manufacturing nickel-cadmium powered EV's on a limited scale. Peugeot Citroën, an alliance of Automobiles Peugeot and Automobiles Citroën, is Europe's third largest manufacturer of conventional automobiles. Peugeot Citroën currently has three EV models in production: the Peugeot 106 Electrique, the Citroën AX Electrique, and the Tulip. To date, the alliance has produced more than 1,000 EV's. The Tulip is a small special two-seater EV designed to complement existing urban transit systems. The alliance is also producing a scooter powered by nickel-cadmium batteries, which can attain a speed of 45 kilometers per hour.

For more than 6 years, Peugeot Citroën has been field testing some 50 EV's at the Atlantic port of La Rochelle. A network of recharging stations was set up around La Rochelle as part of the experiment. Peugeot formally introduced its new 106 Electrique in 1995. The two-door hatchback has three battery packs of 6-volt nickel-cadmium monoblocks. The three packs (a total of 20 monoblocks in series) provide 120 volts to a direct current motor. The nickel-cadmium batteries were being serviced by the manufacturer, SAFT SA, which has a brand-new nickel-cadmium battery manufacturing facility in Bordeaux. The 106 Electrique has a driving range of 80 kilometers and can accelerate from zero to 50 kilometers per hour in 8.5 seconds (PSA Peugeot Citroën, 1997). The EV retails for \$18,150.

In October 1996, British sponsors bought fourteen 106 Electrique's and were field testing them in the Midlands city of Coventry (Simonian, 1996). The handful of hatchbacks and vans were being used by the Coventry City Council, East Midlands Electricity, PowerGen, and the Royal Mail.

In 1994, Peugeot Citroën joined with Générale de Transport et d'Industrie (GTI) and Cegelec to form the LISELEC Group, a futuristic EV rental company. The group is currently testing ten 106 Electrique's in the Paris region and is planning to set up a fleet of EV's for self-service operation throughout the region. Each LISELEC customer would be issued a pass and an associated personal code that would permit him or her to pick up an EV at any one of a network of parking stations and return it to any station of his or her choice. GTI, which operates public transit systems in 87 French towns, is responsible for designing the overall system and managing the parking stations. Cegelec will provide the central control system and the on-line computerized reservation/invoicing equipment. The Tulip would be the first rental EV used in the LISELEC system and is specially designed for this purpose. The vehicle is equipped

with an on-board computer that communicates with the central control station. The Tulip network has the potential to dramatically improve the flexibility and net earnings of most metropolitan transit systems, and could prove to be an important end use for nickel.

Nickel-Based Household, Office, and Industrial Batteries.—Nickel-cadmium, nickel-metal hydride, lithium-ion and improved lead-acid electrochemical systems are also strongly competing with one another for the household, office, and industrial rechargeable battery markets. Improvements are continually being made to each of the systems. Energy density, cycle life, charge retention, shelf life, and performance at extreme temperatures are all being enhanced. France, Germany, Japan, and the United States continue to be the principal manufacturers and users of small-sized nickel-cadmium and nickel-metal hydride batteries. China, the Republic of Korea, and Taiwan also have made tremendous strides in this area since 1990. Japanese companies, in particular, have taken a global approach, building manufacturing plants in Belgium, Indonesia, Mexico and several other countries.

A global system for recycling nickel-cadmium and nickelmetal hydride batteries is rapidly becoming a reality. France, Japan, and the United States all have nationally mandated programs. The U.S. collection and recycling program for small rechargeable batteries is in a period of rapid expansion (England, 1996). The program is administered by the Rechargeable Battery Recycling Corporation (RBRC), a nonprofit public service corporation. RBRC generates revenue for the program by licensing its seal of approval to individual companies involved in the manufacturing, importation, and distribution of rechargeable batteries or battery-operated products. More than 175 companies are currently participating in the program. The Portable Rechargeable Battery Association is also a sponsor and has helped to enlist the participation of county and municipal governments, hospitals, and fire departments. Spent nickel-cadmium, nickel-metal hydride, lithium-ion, and small sealed lead batteries are all being collected under the program. The program is now operating in 19 States at more than 4,500 retail locations. Some 300 counties also have drop-off centers. New projections indicate that, by the year 2005, roughly 70% of the spent nickelcadmium batteries being generated in the United States will be The current recycling rate is about 15%. An estimated 85% of industrial nickel-cadmium batteries are recycled. Inmetco was expecting receipts of spent nickelcadmium batteries in 1997 to be 20% to 25% greater than those of 1996. If the new RBRC program grows as expected, Inmetco could be handling 10,000 tons of batteries by the year 2002. It also helps that Inmetco now has on-site facilities for recovering and refining the accompanying cadmium and can convert it into marketable granules. Closing the cadmium loop removed the last major technical impediment to effective recycling of household and industrial nickel-cadmium batteries and has lessened environmental concerns about the collection program.

A similar battery recycling program exists in Japan. There, the program is being promoted by the Japan Storage Battery

Association (JSBA), which represents 11 battery manufacturers. In 1995, Japanese battery manufacturers sold or exported 867 million nickel-cadmium cells and 305 million nickel-metal hydride cells. Statistics collected by the JSBA indicate that 31% of the 338 million cells sold domestically went into cellular telephones and other communications equipment. Another 25% went into home appliances (VCRs, shavers, etc.). The third largest market was office equipment, which accounted for 16%. The collection system supervised by JSBA feeds spent batteries into four regional recycling plants: Japan Recycle Center (with a processing capacity of 3,000 tons per year of batteries), Kansai Catalyst Ltd. (500 tons per year), Mitsui Mining & Smelting Co. Ltd. (a zinc refiner receiving 750 tons per year), and Toho Zinc Co. Ltd. (an electrolytic zinc refiner receiving 1,700 tons per year). Retailers, waste collectors, product manufacturers, and more than 1,900 municipalities all participate in the program (Fujimoto and Mukunoki, 1997). According to the latest available statistics, in 1994, Japan recycled 1,787 tons of spent nickel-cadmium batteries and 3,109 tons of nickel-cadmium battery scrap. Essentially all of the nickel-cadmium scrap generated in Japan at the battery plants is being recycled. However, the tonnage of spent batteries sent to recyclers is expected to rise dramatically between 1997 and the year 2000 as a result of new regulations, improvements in the JSBAsupervised collection program, and growing battery sales.

Spent nickel-cadmium batteries are being reclaimed by at least six plants in the European Union (Metal Bulletin, 1996). The largest European recycler is Sté. Nouvelle d'Affinage des Métaux S.A.R.L. (SNAM), which has two plants in France—one at Viviez in the Massif Central region and another at St. Quentin-Fallavier near Lyon (Broad, 1997). Together, the two process about 5,400 tons of spent batteries annually. SNAM also has ties to the SAFT NIFE AB recycling operation at Oskarshamn, Sweden, which can process an additional 1,500 tons. Other European recyclers include Hydrometal SA (Belgium), Uniniquel SA (Spain), and TNO/Esdex/Leto (Netherlands).

#### Outlook

Demand for austenitic stainless steel will continue to drive the world nickel market for at least another 20 years. World consumption of stainless steel is expected to grow between 3% and 9% annually from 1997 to the year 2005. This growth rate should increase substantially at some point when the Russian economy inevitably turns around and a rejuvenated Russian industry begins consuming the large amounts of stainless sheet and plate required by a technologically advanced, marketoriented society.

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 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 horrendous bills for repairing highway bridges and similar infrastructure could have been avoided by substituting more expensive, but corrosion-resistant, stainless for traditional carbon steel in the original design. 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 demand for quality stainless kitchenware, food processing equipment, sinks, and plumbing parts.

Demand for austenitic stainless steel has resumed its upward growth in several member countries of the Organization for Economic Cooperation and Development (OECD) that were weakened by the global recession of 1991-93. Stainless production capacity is being expanded in some of the newly industrialized countries of East Asia that successfully weathered the recession. Since 1990, production of austenitic stainless steel has been increasing in the Republic of Korea and Taiwan by more than 10% per year. Since 1994, Brazil and South Africa have become significant producers of stainless steel.

Demand for superalloys is expected to grow despite projected cutbacks in the defense programs of the OECD and Russia. Restructuring of the North American and European aerospace industries has spread to some of their raw material suppliers. The warming of relations between Russia and the United States, together with the peaceful expansion of the European Union, is having a tremendous effect on the nickel market. Russia is now a major source of nickel for the United States. The large stocks of nickel metal held by the U.S. Department of Defense are rapidly being sold off and should be exhausted within 3 years. The decline in orders for aerospacegrade metals and alloys from a downsized United States and Canadian defense industry has forced several of the industry's suppliers to restructure and seek out new civilian markets. The acquisition of Teledyne by Allegheny Ludlum is expected to be just the first step in a restructuring of the entire North American superalloys and specialty steel sector. U.S. specialty steel producers have been feeling pressure from their European competitors for some time.

The second step will be the assimilation of Inco Alloys International (IAI) by Haynes International Inc., an Indiana-based company. On June 11, 1997, Inco Limited announced that it had agreed to sell IAI to Blackstone Capital Partners II Merchant Banking Fund L.P. for approximately \$410 million, excluding fees and expenses (Inco Limited, 1997d). Inco's alloy manufacturing division is one of the world's leading developers and producers of wrought nickel-base alloys. IAI has been supplying superalloys to the aerospace industry for more than 40 years from its plant in Huntington, WV. The division also has operations in Hereford, England; Burnaugh, KY; Elkhart, IN; and Newton, NC.

IAI products are bought by a broad spectrum of industry and have a myriad of applications in addition to aircraft engine

components. Other end products include chemical processing equipment, food handling equipment, turbines and related power generation machinery, flue-gas scrubbers, downhole tubing for oil and gas wells, petrochemical storage tanks, and piping systems of all types. Incoloy, Inconel, Monel, and Nimonic are well known trademarks for families of high-nickel alloys produced by IAI.

Blackstone, a merchant bank based in New York, owns approximately 80% of Haynes. Haynes produces Hastelloy X, Waspaloy, and a variety of other nickel-base high-performance alloys. Blackstone is planning to combine the operations of Haynes and IAI, creating one of the largest producers of superalloys in the world (Coplan, 1997; Sacco, 1997). The new company would face a number of competitors, including Allegheny Teledyne Inc., Cannon-Muskegon Corp., Carpenter Technology Corp., Howmet Corp., Special Metals Corp., and VDM Technologies Corp. Approval still must be obtained from regulatory authorities and antitrust examiners (Ryan's Notes, 1997). The sale was scheduled to close in the fall of 1997 and should give Inco an after-tax gain of about \$85 million. Part of the money would be applied to the debt incurred in acquiring the Voisey's Bay nickel-copper-cobalt deposit.

A third step is the proposed certification of Russian-made aerospace alloys for use by U.S. aircraft manufacturers. Verkhnaya Salda Metallurgical Production Association (VSMPO), Russia's only supplier of titanium alloy, recently had its Ti-6Al-4V aircraft quality ingot approved by Boeing, the Wyman-Gordon Co., and the Shultz Steel Co. (Karasyov, 1995). VSMPO also produces nickel-based high temperature alloys. Norilsk Nickel has strong ties to several capable metallurgical institutes in Russia and could gain North American industry support for Russian nickel-base superalloys through the company's long-established marketing arm in Western Europe.

EV's have begun to emerge from assembly plants in Western Europe, the United States, and Japan. Around the world, automobile manufacturers, metal producers, electric utility managers, environmentalists, and regulatory officials are all watching to see how these first mass-produced EV's will be received by the general public. Five different battery chemistries are being used: nickel-cadmium, nickel-metal hydride, valve-regulated lead-acid (VRLA), lithium-ion, and zinc-air. The outcome could significantly increase nickel demand and possibly even change nickel production technology if one of the two nickel batteries wins out in the competition.

The market for nickel-based batteries is expected to grow at least 6% per year over the next 10 years even if American automobile manufacturers decide not to put either nickel-cadmium or nickel-metal hydride cells in their new electric vehicles. Nickel-cadmium and nickel-metal hydride batteries are strong contenders for the rapidly growing electric scooter/bicycle market and will still be used in rechargeable power tools, home appliances, and other household equipment because of cost constraints. Nickel-cadmium and nickel-metal hydride batteries continue to compete head-on with lithium-ion alternatives in the portable electronics sector. However, over the last 3 years, nickel-metal hydride and lithium-ion batteries

have been gaining ground against nickel-cadmium for some electronic end uses. The bulk of the nickel-metal hydride batteries are currently being used in communications and office equipment. In 1993, nickel-metal hydride batteries were introduced to the general public in Japan for the first time. Since then, sales have mushroomed. In Japan, nickel-metal hydride batteries have already captured 49% of the office equipment market, 32% of the communications market, and 4% of the home appliances market (Fujimoto and Mukunoki, 1997). Nickel-cadmium batteries continue to dominate the emergency lighting market.

The development of the Voisey's Bay deposit is expected to have a major impact on the world nickel supply, sharply reducing concerns about future shortages of the metal. Recent drilling has delineated additional resources at depth in the immediate area of the discovery site, spurring nickel exploration throughout all of eastern Canada as well as in Greenland. The discovery of the Voisey's Bay deposit has forced economic geologists to change some of their concepts on the genesis of massive sulfide deposits. This, in turn, has caused exploration companies to rethink some of their long-range targeting strategies for other parts of the Northern Hemisphere.

Western nickel producers have largely adjusted to the massive Russian exports of cathode. Supplies of stainless scrap have tightened, and the nickel industry is again expanding mining and smelting capacity on a global basis. Considerable effort is being expended on developing hydrometallurgical techniques that will improve the recovery of nickel from laterites. One of the more promising technologies is a combination of pressure acid leaching and solvent extraction.

#### **References Cited**

- Aerospace Industries Association of America, Inc., 1996, Yearend review and forecast: Aerospace Industries Association of America, Inc., Statistics #96-69, Series #02-01, December 11, 6 p. plus 16 assorted tables and charts. See also: 1996 yearend review and forecast updates; Orders, shipments, and backlog of large commercial jet transport aircraft, first quarter, 1997, Statistics #97-18, Series 23-02, April 30, 1997, 3 p.
- Akre, B.S., 1996, GM opens electric era—carmaker hopes EV1 gives West a charge: Washington Times, November 15, p. B-8.
- American Iron and Steel Institute, 1997a, Annual statistical report—1996: American Iron and Steel Institute, 122 p.
- ———1997b, Quarterly production of stainless and heat resisting raw steel (AIS 104): American Iron and Steel Institute, fourth quarter 1996, 2 p.
- Anaconda Nickel Limited, 1997, Report for quarter ended June 30, 1997: West Perth, Western Australia, Anaconda Nickel Limited. (Accessed September 5, 1997, on the World Wide Web at URL http://www.oberon.com.au/ Anaconda\_Nickel/).
- Anderson, S., 1996, Nickel—breaking new ground: Engineering & Mining Journal, v. 197, no. 3, March, p. 43-47.
- BHP Minerals Limited, 1996, Nickel JV in Indonesia: Melbourne, Australia, BHP Minerals Global Report, September 1, p. 1.
- Billiton, Plc., 1997, Information memorandum for shareholders of Gencor Limited: London, UK, Billiton Plc., July 4, 197 p.
- Broad, Alex, 1997, Snam snaps up change: Metal Bulletin Monthly, no. 319, July, p. 61.
- Brockelbank, T., 1996a, Inco settles on site for Voisey's Bay smelter: The Northern Miner, v. 82, no. 41, December 9, p. 1-2.
- ———1996b, Lifting of ban prompts Quebec staking rush: The Northern Miner, v. 82, no. 33, October 14, p. 1-2.
- ———1996c, Quebec Gov't stakes nickel as private sector looks on: The

- Northern Miner, v. 82, no. 28, September 9, p. 1-2.
- Buchan, David, 1997a, Protagonists seek deal over Eramet: London Financial Times, May 5, p. 20.
- ——1997b, Seam of trouble—A row in New Caledonia sets a bad precedent for French privatisations: London Financial Times, April 8, p. 14.
- Cominco Ltd., 1997, Annual report—1996: Vancouver, British Columbia, 61 p.
- Coplan, Stephen, 1997, Nickel alloy buyout sealed—Blackstone to merge Inco Alloys with Haynes: American Metal Market, v. 105, no. 113, June 12, p. 1.
- du Luart, Roland, 1997, Rapport no. 212: Mission Nouvelle-Calédonie [Report No. 212: Mission to New Caledonia] Senat - Commission des Finances (In French). (Accessed May 5, 1997, on the World Wide Web at URL http://www.senat.fr/rap/r96-212/r96-212\_mono.html).
- England, C.N., 1996, Recycling America's rechargeable batteries in Sources of cadmium in the environment, OECD Cadmium Workshop, Saltsjöbaden, Sweden, October 16-20, 1995, Proceedings: Paris, Organisation for Economic Co-operation and Development, p. 195-200.
- Eramet Group, 1997, Annual report—1996: Paris, France, 36 p.
- Falconbridge Dominicana, C. por A., 1997, Annual report—1996: Santo Domingo, N.D., Dominican Republic, 17 p.
- Falconbridge Limited, 1996, Annual report—1995: Toronto, Ontario, 60 p.
  ——1997, Annual report—1996: Toronto, Ontario, 60 p.
- Fujimoto, Kinya, and Mukunoki, Junij, 1997, Status of Ni-Cd battery recycling in Japan in NiCad '96—Edited proceedings of conference held in Barcelona, Spain, September 30-October 1, 1996: London, International Cadmium Association, p. 44-49.
- Hanewald, R.H., Schweers, M.E., and Liotta, J.J., 1996, Recycling nickel-cadmium batteries through the High Temperature Metal Recovery process and new cadmium recovery facility in Proceedings of 11th Annual Battery Conference on Applications and Advances, Long Beach, CA, January 9-12, 1996: IEEE, 0-7803-2994-5, p. 207-212.
- Heinzl, Mark, 1996, Diamond Fields accepts Inco's takeover offer: Wall Street Journal, v. 227, no. 67, April 4, p. A3 and A7.
- Holusha, John, 1996, Trying to avoid WHX takeover, Teledyne selects another suitor: New York Times, v. 145, no. 50,385, April 2, p. D1 and D22.
- Inco Limited, 1997a, Annual report—1996: Toronto, Ontario, 68 p.
- ——1997b, Inco announces new nickel zone at Voisey's Bay deposit: Inco Media Information, press release no. 3/97, January 31, 2 p.
- ———1997c, Inco Limited and Sumitomo Metal Mining Co., Ltd. sign agreement in principle on Sumitomo refining process: Inco Media Information, press release no. 9/97, May 14, 1 p.
- ——1997d, Inco Limited announces agreement to sell its alloys business to an affiliate of Blackstone Capital Partners: Inco Media Information, press release no. 10/97, June 11, 2 p.
- ——1997e, Inco to move forward with pilot plant and engineering for Goro Nickel Project: Inco Media Information, press release no. 16/97, September 17, 2 p.
- The International Metals Reclamation Co., Inc., 1997, Inmetco—Recycling to sustain our natural resources: Ellwood City, PA, Inmetco press release, January, 1 p.
- International Nickel Study Group, 1997a, World nickel statistics: The Hague, The Netherlands, International Nickel Study Group, v. 7, no. 7, July, 75 p.
- ———1997b, World nickel statistics: The Hague, The Netherlands, International Nickel Study Group, v. 7, no. 10, October, 104 p.
- Ishikawa, Yukio, 1994, Development and industrialization for a new highly nickel refining process: Metallurgical Review of The Mining and Materials Processing Institute of Japan, v. 11, no. 2, December, p. 1-15.
- Karasyov, V., 1995, Russian producer targets foreign markets: Metal Bulletin Monthly, October, no. 298, p. 61.
- Kimberley, William, 1995, Frankfurt '95 spotlight in Electric & Hybrid Vehicle Technology '95: Dorking, United Kingdom, UK & International Press, p. 64-71.
- Metal Bulletin, 1996, Bringing back batteries: Metal Bulletin, no. 8107, August 29, p. 26.
- Norton, Erle, and Andy Pasztor, 1996, Ludlum agress to a merger with Teledyne: Wall Street Journal, v. 227, no. 65, April 2, p. A3-A4.
- Outokumpu Oy, 1997, Annual report—1996: Espoo, Finland, 78 p.
- Platt's Metals Week, 1997, Norilsk forecasts 20% increase in nickel production: Platt's Metals Week, v. 68, no. 78 [sic 8], February 24, p. 12.
- Presidential Documents, 1996, Executive Order 13031 of December 13, 1996–Federal alternative fueled vehicle leadership: Federal Register, v. 61,

no. 243, December 17, p. 66529-66531.

PSA Peugeot Citroën, 1997, PSA Peugeot Citroën, the Générale de Transport et d'Industrie (GTI) and CEGELEC test the LISELEC project—The self-service electric car: PSA Peugeot Citroën press release, July 22, 2 p. (Accessed August 12, 1997, on the World Wide Web at URL http://www.psa.fr/en\_psaEE0096.html).

Rechtin, M., 1996, Calif. kills '98 EV mandate: Automotive News, v. 70, no. 5652, April 1, p. 1 and 53.

Rose, Frederick, 1996, California eases environmental rules for introduction of zero-emission autos: Wall Street Journal, v. 227, no. 64, April 1, p. B8B.

Ryan's Notes, 1997, Inco sells alloys unit to Haynes: Ryan's Notes, v. 3, no. 24, June 16, p. 2.

Sacco, J.E., 1997, Haynes exec—Inco's processing is a plus: American Metal Market, v.105, no. 114, June 13, p. 16.

Sherritt International Corporation, 1997, Annual report—1996: Toronto, Canada, 42 p.

Simonian, H., 1996, Electric cars experiment gets the green light: Financial Times (London), October 15, p. 10.

Suttill, K.R., 1994, Cuba turns to the pragmatists *in* 1995 E&MJ International Directory of Mining: Chicago, IL, Intertec Publishing Co., p. 172-180.

Trillion Resources Ltd., 1997, Annual report—1996: Kanata, Ontario, p. 7.

Upton, Doug, 1997, Nickel—constrained by stainless steel inventories: Engineering & Mining Journal, v. 198, no. 3, March, p. 24-27.

Voisey's Bay Nickel Company Limited, 1996a, Argentia selected as proposed site for smelter/refinery complex: St. John's, Newfoundland, Voisey's Bay Nickel Company Limited news release, November 29, 2 p.

——1996b, The Voisey's Bay mine/mill project [project description report]:
 Voisey's Bay Nickel Company Limited, September 26, 55 p. plus Appendix A

———1996c, The Voisey's Bay smelter/refinery project [project description report]: Voisey's Bay Nickel Company Limited, December 5, 77 p.

Western Mining Corporation Holdings Limited, 1995, FY 1995 Annual report to shareholders: Melbourne, Australia, p. 23.

WMC Limited, 1997, FY 1997 Annual report to shareholders: Southbank, Victoria, Australia, 96 p.

Wrigley, Al, 1997, Battery may go the distance: American Metal Market, v. 105, no. 153, August 8, p. 8.

### SOURCES OF INFORMATION

#### **U.S.** Geological Survey Publications

Nickel. Ch. in Mineral Commodity Summaries, annual.<sup>1</sup>

Nickel. Ch. in Minerals Yearbook, annual.1

Nickel. Ch. in United States Mineral Resources. U.S. Geological Survey Professional Paper 820, 1973.

Nickel. International Strategic Minerals Inventory Summary Report. U.S. Geological Survey Circular 930-D, 1985.

Nickel. Mineral Industry Surveys, monthly.<sup>1</sup>

#### Other

American Metal Market, daily.

Chemical Abstracts.

Company annual reports.

Engineering and Mining Journal, monthly.

Natural Resources—Canada (Ottawa).

International Nickel Study Group (The Hague).

Metal Bulletin (London), semiweekly and monthly.

Mining Journal (London), weekly, and Mining Annual Review.

Nickel. Ch. in Mineral Facts and Problems. U.S. Bureau of Mines Bulletin 675, 1985.

Nickel Development Institute (Toronto).

Nickel Producers Environmental Research Association.

Platt's Metals Week, weekly.

Roskill Information Services Ltd. Reports (London).

World Bureau of Metals Statistics (London).

<sup>&</sup>lt;sup>1</sup>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)

	1992	1993	1994	1995	1996
United States:					
Mine production	6,670	2,460		1,560	1,330
Plant production	8,960	4,880		8,290	15,100
Secondary recovery from purchased scrap:					
From ferrous scrap	47,700	46,600	48,900	54,400	48,800
From nonferrous scrap	8,140	7,460	9,690	10,200 r/	10,400
Exports:					
Primary	8,560	7,180	7,420	9,750	13,100
Secondary	25,300	26,000	34,500	41,800	33,600
Imports for consumption:					
Ore	3,580	2,970		8,200	15,000
Primary	119,000	126,000	127,000	149,000	142,000
Secondary	9,510	6,710	6,070 r/	7,930	8,060
Consumption:					
Reported:					
Primary	101,000 r/	105,000 r/	108,000 r/	124,000	116,000
Secondary (purchased scrap) 2/	55,900	54,000	58,600	64,500 r/	59,200
Total	157,000 r/	159,000	166,000	189,000 r/	175,000
Apparent:					
Primary	119,000	122,000	133,000 r/	152,000 r/	149,000
Secondary (purchased scrap)	40,300	36,600	30,500 r/	29,500 r/	33,600
Total	159,000	158,000	164,000 r/	181,000 r/	183,000
Stocks, yearend:					
Government	33,800	31,600	26,800	19,800	15,900
Producers and traders	10,100	15,700	10,200	12,700 r/	11,200
Consumer:					
Primary	12,300	11,100	8,040 r/	8,130	8,690
Secondary	5,240	3,360	3,020 r/	4,150	4,210
Employment, yearend:					
Mine	10	2	1	17 r/	8
Smelter	250	33	22	253 r/	253
Port facility	23	5	3	25	23
Price, cash, London Metal Exchange:					
Per metric ton	\$7,001	\$5,293	\$6,340	\$8,228	\$7,501
Per pound	\$3.176	\$2.401	\$2.876	\$3.732	\$3.402
World: Mine production	1,010,000 r/	926,000 r/	929,000 r/	1,030,000 r/	1,080,000 e/

e/ Estimated. r/ Revised.

<sup>1/</sup> 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 considerable 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)

	1995	1996
Kind of scrap:		
Aluminum-base 2/	3,280	3,250
Copper-base	2,720	3,120
Ferrous-base 3/	54,400	48,800
Nickel-base	4,170 r/	4,050
Total	64,500 r/	59,200
Form of recovery:		
Aluminum-base alloys 4/	3,280	3,250
Copper-base alloys	4,540 r/	4,910
Ferrous alloys	54,400	48,800
Nickel-base alloys	2,300 r/	2,160
Miscellaneous and unspecified		37
Total	64,500 r/	59,200

- r/ Revised.
- $1/\,\textsc{Data}$  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	1995	1996
Primary:		
Metal	93,700 r/	86,300
Ferronickel	21,800 r/	22,900
Oxide and oxide sinter 2/	3,250	1,460
Chemicals	4,310	4,720
Other	1,440	804
Total primary	124,000	116,000
Secondary (scrap) 3/	64,500 r/	59,200
Grand total	189,000 r/	175,000

- r/ Revised.
- $1/\,\mbox{Data}$  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.

# ${\bf TABLE~4} \\ {\bf U.S.~CONSUMPTION~OF~NICKEL~IN~1996,~BY~USE~1/}$

(Metric tons of contained nickel)

			Oxide						
		_	and						_
		Ferro-	oxide		Other	Total	Secondary	Grand	total
Use	Metal	nickel	sinter	Chemicals	forms	primary	(scrap)	1996	1995
Cast irons	175	W	(2/)	W	43	218	345	563	491 r/
Chemicals and chemical uses	1,100		W	4,220		5,310		5,310	5,210 r/
Electric, magnet, expansion alloys	W					W	W	W	W
Electroplating (sales to platers)	16,200	(2/)	W	44	W	16,200	W	16,200	15,600
Nickel-copper and copper-nickel alloys	3,250	W	W		W	3,250	4,050	7,300	8,510 r/
Other nickel and nickel alloys	17,800	W	W		W	17,800	1,930	19,700	21,800 r/
Steel:									
Stainless and heat resistant	24,100	21,800	426		70	46,400	47,600	94,000	103,000 r/
Alloys (excludes stainless)	5,390	W	W		W	5,390	851	6,240	9,570 r/
Superalloys	12,600		(2/)	W	W	12,600	W	12,600	14,100 r/
Other 3/	5,680	1,110	1,030	459	691	8,970	4,440	13,400	10,300 r/
Total reported	86,300	22,900	1,460	4,720	805	116,000	59,200	175,000	189,000 r/
Total all companies, apparent	XX	XX	XX	XX	XX	149,000	33,600	183,000	181,000 r/

r/Revised. W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.

 ${\bf TABLE~5}$  NICKEL IN CONSUMER STOCKS IN THE UNITED STATES, BY FORM 1/

(Metric tons of contained nickel)

Form	1995	1996
Primary:		
Metal	6,190 r/	6,150
Ferronickel	<del></del> 674	1,620
Oxide and oxide sinter	324	181
Chemicals	808	565
Other	129	177
Total primary	8,130	8,690
Secondary (scrap)	4,150	4,210
Grand total	12,300	12,900

r/ Revised.

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

<sup>2/</sup> Less than 1/2 unit.

<sup>3/</sup> Includes batteries, catalysts, ceramics, coinage, other alloys containing nickel, and data indicated by symbol "W."

 $<sup>1/\,\</sup>mbox{Data}$  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)

	1	1995	199	96	
		Value		Value	
Class	Quantity	(thousands)	Quantity	(thousands)	
Unwrought primary:	•				
Cathodes, pellets, briquets, and shot	1,310	\$11,400	586	\$4,630	
Ferronickel	807	6,590	3,330	32,700	
Powder and flakes	1,230	13,900	1,060	12,600	
Metallurgical-grade oxide 2/	3,490	7,730	4,210	6,750	
Chemicals: 3/	•				
Catalysts	2,210	83,900	3,250	97,000	
Salts 4/	714	10,100	692	7,980	
Total	9,750	134,000	13,100	162,000	
Unwrought secondary: 5/					
Stainless steel scrap	27,600	325,000	22,800	234,000	
Waste and scrap	14,200	58,600	10,900	56,600	
Total	41,800	384,000	33,600	290,000	
Grand total	51,500	517,000	46,800	452,000	
Wrought:					
Bars, rods, profiles and wire	205	2,150	157	2,300	
Sheets, strip and foil	117	2,180	188	2,720	
Tubes and pipes	154	1,420	95	1,360	
Total	476	5,750	440	6,370	
Alloyed (gross weight):					
Unwrought alloyed ingot	4,170	41,000	5,710	56,600	
Bars, rods, profiles and wire	4,920	79,900	4,770	82,300	
Sheets, strip and foil	6,380	104,000	8,200	113,000	
Tubes and pipes	1,240	28,000	1,270	31,700	
Other alloyed articles	2,150	36,500	3,520	53,000	
Total	18,900	289,000	23,500	336,000	

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

Sources: Bureau of the Census and Journal of Commerce.

TABLE 7 U.S. EXPORTS OF NICKEL PRODUCTS IN 1996, BY COUNTRY 1/

(Metric tons of contained nickel 2/)

	Cathodes, pellets, and	Powder		Metal- lurgical	Waste	Stainless				
	briquets,	and	Ferro-	grade	and	steel		Tota	1	Wrought
Country	(unwrought)	flakes	nickel	oxide 3/	scrap	scrap	Chemicals	1996	1995	nickel 4/
Australia		2			108	8	6	124	164	6
Belgium		35				158	195	388	2520	4
Canada	307	707	39	4030	6370	4080	856	16400	18600	43
China		(5/)			121	123	26	270	372	3
Colombia	3	12			15	17	22	69	34	1
Finland		(5/)			30	(5/)		30	37	
France	2	14		2	25	8	23	74	280	16
Germany	9	26		2	692	17	22	768	730	15
India		4	1590		66	134	24	1820	354	5
Italy		4			(5/)	3	16	23	39	
Japan	(5/)	44	23	1	1140	1940	724	3880	5300	14
Korea, Republic of	(5/)	23		(5/)	17	5930	53	6030	8010	6
Mexico	175	40	11	7	14	18	278	543	524	145
Netherlands	28	13			83	124	21	269	1400	5
South Africa		1	359	20		993	19	1390	779	(5/)

See footnotes at end of table.

<sup>2/</sup> Chemical-grade oxide is included with the "Salts" category.
3/ For the different salts, the nickel contents are assumed to be as follows: chlorides, 25%; sulfates, 22%; other salts,

<sup>22%;</sup> and oxide, sesquioxide and hydroxide, 65%. The typical catalyst is assumed to have a nickel content of 22%.

<sup>4/</sup> Excludes nickel carbonate (see schedule B 2836.99.9050).

<sup>5/</sup>The nickel content of waste and scrap is assumed to be 50%, while that of stainless steel scrap has been shown to be about 7.5%.

# TABLE 7--Continued U.S. EXPORTS OF NICKEL PRODUCTS IN 1996, BY COUNTRY 1/

(Metric tons of contained nickel 2/)

	Cathodes, pellets, and briquets,	Powder and	Ferro-	Metal- lurgical grade	Waste and	Stainless steel		Tota	1	Wrought
Country	(unwrought)	flakes	nickel	oxide 3/	scrap	scrap	Chemicals	1996	1995	nickel 4/
Spain	(5/)	2		(5/)		4860	3	4860	5160	4
Sweden		10			2010	643	(5/)	2670	2380	1
Taiwan		11	1300		9	3110	105	4540	1520	3
United Kingdom	7	33	1	6	90	119	78	334	451	77
Other	55	79	(5/)	144	87	457	1470	2290	2930 r/	93
Total	586	1,060	3,330	4,210	10,900	22,800	3,940	46,800	51,500	440

r/ Revised.

- 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.

 ${\bf TABLE~8} \\ {\bf U.S.~IMPORTS~FOR~CONSUMPTION~OF~NICKEL~PRODUCTS,~B~Y~CLASS~1/}$ 

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

	199:	5	1996		
		Value		Value	
Class	Quantity	(thousands)	Quantity	(thousands)	
Unwrought primary:					
Cathodes, pellets, briquets, and shot	118,000	\$959,000	113,000	\$890,000	
Ferronickel	16,700	129,000	16,000	111,000	
Flakes		4,690	1	55	
Powder	8,720	89,100	9,700	101,000	
Metallurgical-grade oxide	530	5,110	464	4,220	
Chemicals:	_				
Catalysts	2,420	34,200	1,540	61,500	
Salts 3/	1,780	22,100	1,730	22,800	
Total	149,000	1,240,000	142,000	1,190,000	
Unwrought secondary:					
Stainless steel scrap	3,190	33,800	3,790	28,500	
Waste and scrap	4,740	47,100	4,280	35,200	
Total	7,930	80,900	8,060	63,800	
Grand total	157,000	1,320,000	150,000	1,250,000	
Wrought:					
Bars, rods, profiles and wire	170	2,540	242	3,750	
Sheets, strip and foil		23,900 r/	341	9,090	
Tubes and pipes	94	2,020	54	1,230	
Total	2,310 r/	28,400 r/	636	14,100	
Alloyed (gross weight):					
Unwrought alloyed ingot	3,000	28,200	2,780	28,300	
Bars, rods, profiles and wire	3,210	39,900	3,920	58,500	
Sheets, strip and foil	1,510	22,200	1,520	24,800	
Tubes and pipes	1,040	21,000	832	17,500	
Other alloyed articles	377	11,500	1,190	18,700	
Total	9,140	123,000	10,200	147,800	

r/ Revised.

Sources: Bureau of the Census and Journal of Commerce.

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

<sup>2/</sup> The nickel contents are assumed to be as follows: metallurgical-grade oxide, 77%; waste and scrap, 50%; and stainless steel scrap, 7.5%. The chemical 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.

 $<sup>1/\,\</sup>mbox{Data}$  are rounded to three significant digits; may not add to totals shown.

<sup>2/</sup> 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.

<sup>3/</sup> Excludes nickel carbonate (see HTSUS 2836.99.5000).

# ${\bf TABLE~9}$ U.S. IMPORTS FOR CONSUMPTION OF NICKEL PRODUCTS, BY COUNTRY 1/

(Metric tons of contained nickel 2/)

	Cathodes, pellets, and	Powder		Metal- lurgical	Waste	Stainless				
	briquets	and	Ferro-	grade	and	steel		To	otal	Wrought
Country	(unwrought)	flakes	nickel	oxide 3/	scrap	scrap	Chemicals	1996	1995	nickel 4/
Australia	13,300	1,470		67	10		24	14,900	13,800	
Austria		117	157					274	139	14
Belgium		3			19		322	344	554	
Brazil	118	1	350		32			501	2,800	
Canada	47,800	6,640		369	1,150	1,900	650	58,500	54,400	26
China		(5/)			5		22	27	235	1
Colombia			1,390		26	1	1	1,420	2,330	
Dominican Republic			9,150		135	4		9,290	8,270	
Finland	3,830	437				1	469	4,740	2,870	(5/)
France	1,460	2			555	5	236	2,260	2,010	88
Germany	147	73			305	4	289	818	525	408
Japan	301	63			158	127	507	1,160	459	55
Mexico					90	1,600	248	1,940	1,560	1
New Caledonia			4,160					4,160	4,200	
Norway	24,300				20			24,300	19,200	
Russia	17,200	734	418		259	1	4	18,600	34,600	
South Africa	1,170		30					1,200	2,570	
United Kingdom	865	109		(5/)	819		143	1,940	2,740	15
Zimbabwe	1,730							1,730	1,900	
Other	625	43	323	28	692	139	350	2,200	1,710	28
Total	113,000	9,700	16,000	464	4,280	3,790	3,270	150,000	157,000	636

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

Source: Bureau of the Census.

<sup>2/</sup> 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%; and other salts which are assumed to be 22% nickel. The typical catalysts are assumed to have a content of 22%.

<sup>3/</sup> Primarily oxide rondelles and sinter.

<sup>4/</sup> Not included in "Total."

<sup>5/</sup> Less than 1/2 unit.

 ${\bf TABLE~10}$  NICKEL: WORLD MINE PRODUCTION, BY COUNTRY 1/2/

(Metric tons of nickel content)

Country	1992	1993	1994	1995	1996 e/
Albania (content of ore) e/	150	75			
Australia (content of concentrate)	57,683	64,717	78,962	98,467 r/	113,134 3/
Botswana (content of ore milled)	23,000	23,000	19,041	18,672	24,200 3/
Brazil (content of ore)	29,372	32,154	32,663	25,469 r/	25,600
Burma (content of ore)	9	67	50 e/	50 e/	50
Canada (content of concentrate)	186,384	188,080	149,886	180,984	183,059 p/
China (content of concentrate) e/	32,800	30,700	36,900	41,800 r/	43,000
Colombia (content of laterite ore)	23,347	22,831	26,141	24,194	27,700 3/
Cuba (content of oxide, oxide sinter, sulfide) 4/	32,190	30,227	26,926	42,696	51,613 3/
Dominican Republic (content of laterite ore)	42,641	37,423	45,588 r/	44,051 r/	45,000
Finland (content of concentrate)	10,311 r/	8,862 r/	7,652	4,382	4,000
Greece (content of laterite ore)	17,000	12,940	18,821	19,947	20,000
Indonesia (content of ore)	77,600	65,757	81,175	88,183	90,000
Kazakstan e/	8,500	8,500	8,500	9,900 3/	9,800
New Caledonia (content of ore)	113,000	97,092	97,323	121,457	142,200 3/
Norway (content of concentrate)	3,398	3,462	2,938	2,992 r/	3,000
Philippines	13,022	7,663	9,895	15,075	14,700
Russia e/	280,000	244,000 3/	240,000	251,000	230,000
Serbia and Montenegro (content of ferronickel					
produced)	1,857	443	603	962	2,556 3/
South Africa (content of concentrate)	28,400	29,868	30,751	29,803	33,613 3/
Ukraine (content of ferronickel produced) e/	5,900 3/	3,000 r/	1,400 r/3/	1,400 r/	500
United States (content of local ore processed)	6,670	2,460		1,560 p/	1,330 3/
Zimbabwe (content of concentrate)	12,378	12,769	13,836	11,721	11,600
Total	1,010,000 r/	926,000 r/	929,000 r/	1,030,000 r/	1,080,000

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

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

#### (Metric tons of nickel content)

Country 3/ and product	1992	1993	1994	1995	1996 e/
Albania: Metal e/	50	50	50	50	50
Australia: Unspecified	57,000	55,000	67,000	77,000 r/	74,000 4/
Austria: Ferronickel	3,900	3,200	2,100 e/	2,500 e/	2,000
Brazil: 5/					
Ferronickel	8,742	8,683	8,815	8,497	8,500
Metal	5,926	7,022	7,795	7,179	7,200
Total	14,668	15,705	16,610	15,676	15,700
Canada: Unspecified 6/	135,200	123,140	105,144	121,523	126,593 4/
China: Metal e/	30,800	30,500	31,300	38,900 r/	43,300
Colombia: Ferronickel	20,195	20,181	20,833	24,565	22,934 4/
Cuba: Oxide sinter 7/	16,717	15,999	13,930	21,388	27,024 4/
Czechoslovakia: 8/ Metal 9/	1,621	XX	XX	XX	XX
Dominican Republic: Ferronickel	27,530	23,859	30,766	30,893	30,400 4/
Finland:					
Chemicals	2,890	3,126	4,192	4,000 e/	4,000
Metal	14,781	14,800	16,902	16,927 r/	16,000
Total	17,671	17,926	21,094	20,927 r/	20,000
France:					
Chemicals e/	1,200	1,200	1,200	1,200	1,200
Metal	6,750	9,120	10,041	10,306	8,500
Total e/	7,950	10,300	11,200	11,500	9,700
See footnotes at end of table					

See footnotes at end of table.

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

<sup>2/</sup> 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. Between 1992 and 1996, the Republic of Korea, the United States, and five members of the European Union reported receiving ferronickel originating from Macedonia, but definitive information on the output of the Kavadarci operation was not available. North Korea may also have an active nickel mine, but again information is inadequate to make reliable estimates of outputs. Table includes data available through July 22, 1997.

3/ Reported figure.

<sup>4/</sup> Data represent nickel plus cobalt content in the ratio of roughly 80 to 1.

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

#### (Metric tons of nickel content)

Country 3/ and product	1992	1993	1994	1995	1996 e/
Greece: Ferronickel	15,420	10,934	16,197	17,164	18,000
Indonesia: Ferronickel	5,506	5,266	5,745	10,735	11,000
Japan:					
Ferronickel	57,447	51,120	50,186	69,876 r/	65,374 4/
Metal	22,038	23,108	25,311	26,824	26,564 4/
Oxide sinter	27,520	28,812	34,711	35,966 r/	36,200 4/
Chemicals	2,427	2,258	2,400	2,297	2,344 4/
Total	109,432	105,298	112,608	134,963 r/	130,482 4/
Korea, Republic of: Metal e/	(10/)	(10/)	(10/)	(10/)	(10/)
New Caledonia: Ferronickel	31,895	36,850	39,488	42,200	41,000
Norway: Metal	55,686	56,817	67,955	53,237	61,582 4/
Russia: e/11/					
Ferronickel	6,000	6,800	9,800	14,000	10,000
Metal	221,000	167,000	165,000	181,000	175,000
Oxide sinter	15,000	10,200	4,600	4,100 r/	3,000
Chemicals	3,000	2,000	2,000	2,000	2,000
Total	245,000	186,000	181,000	201,000 r/	190,000
Serbia and Montenegro: Ferronickel	1,857	443	603	962	2,556 4/
South Africa: Metal	27,621	29,868	30,751	29,803	33,100
Sweden: Metal e/	500	500	500	500	500
Taiwan: Metal	(10/)	(10/)	(10/)	(10/)	(10/)
Ukraine: Ferronickel e/	5,900 4/	3,000 r/	1,400 r/	1,400 r/	500
United Kingdom: Metal e/	28,000	28,000	28,400 4/	31,800	32,000
United States: Ferronickel	8,960	4,880		8,290	15,100 4/
Zimbabwe: Metal 12/	10,349	11,097	13,516	10,864 r/	9,793 4/
Grand total	879,000	795,000	818,000 r/	908,000	917,000
Of which:					
Ferronickel	193,000	175,000 r/	186,000 r/	231,000 r/	227,000
Metal	425,000	378,000	397,000	407,000 r/	414,000
Oxide sinter	59,200	55,000	53,200	61,500 r/	66,200
Chemicals	9,520	8,580	9,790	9,500	9,540
Unspecified	192,000	178,000	172,000	199,000 r/	201,000
/E - 1 /D 1 1 777 37 - 1 11	*				*

e/ Estimated. r/ Revised. XX Not applicable.

- 1/ World totals, U.S. data, and estimated data are rounded to three significant digits; may not add to totals shown.
- 2/ Table includes data available through July 22, 1997.

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. Between 1992 and 1996, the Republic of Korea, the United States, and five members of the European Union reported receiving ferronickel originating from Macedonia, but definitive information on the output of the Kavadarci operation was not available. Data supplied by the International Nickel Study Group suggest that, since 1991, Macedonian ferronickel production has ranged from 2,000 to 4,500 metric tons per year of contained nickel. Several countries produce nickel-containing matte, but output of nickel in such materials has been excluded from this table in order to avoid double counting. Countries producing matte include the following, with output indicated in metric tons of contained nickel: Australia (estimated): 1992-96--55,000 (revised); Botswana: 1992--18,918; 1993--19,619; 1994--19,042; 1995--18,089; and 1996--23,200; Canada (estimated): 1992-96--40,000; Indonesia: 1992--39,300; 1993--37,000; 1994--48,400; 1995--49,300; and 1996--49,000; New Caledonia: 1992--7,475; 1993--10,883; 1994--10,641; 1995--10,143; and 1996--9,850.

- 4/ Reported figure.
- 5/ Brazil is believed to also produce nickel oxide, but information is not available on which to base estimates.
- 6/ Nickel contained in products of smelters and refineries in forms which are ready for use by consumers.
- 7/ Cuba also produces nickel sulfide but, because it is used as feed material elsewhere, it is not included to avoid double counting. Output of processed sulfide was as follows, in metric tons of contained nickel: 1992--14,116; 1993--12,973; 1994--11,857; 1995--19,456; and 1996--24,589. 8/ Dissolved Dec. 31, 1992.
- 9/ All production for Czechoslovakia in 1992 came from Slovakia. Production for 1993-96 is estimated to be zero.
- 10/ Nickel metal production figures for the Republic of Korea and Taiwan are not included because the production is derived wholly from imported metallurgical oxides and to include them would result in double counting. Metal estimates are as follows in metric tons: the Republic of Korea: 1992-96--10,000; Taiwan: 1992--10,000; 1993--9,000; and 1994-96--10,000.
- 11/ Includes production from sulfidized concentrates shipped from Cuba for toll refining.
- 12/ Excludes production from matte shipped from Botswana for toll refining.

FIGURE 1
LONDON METAL EXCHANGE CASH PRICE AND STOCKS
1990-97

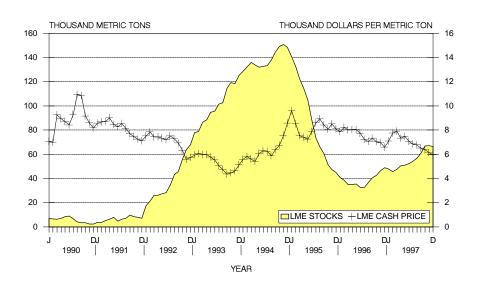
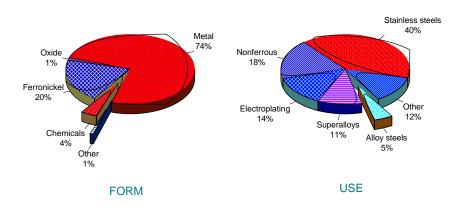
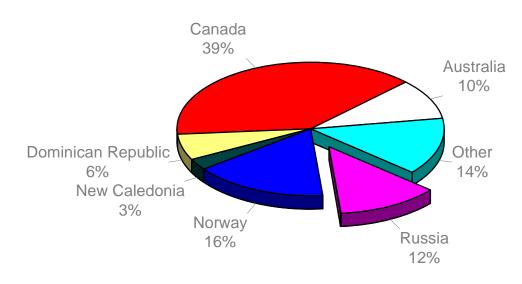


FIGURE 2
U.S. PRIMARY NICKEL CONSUMPTION, BY FORM AND USE 1996



116,000 METRIC TONS

FIGURE 3
COMBINED U.S. PRIMARY AND SECONDARY NICKEL
IMPORTS, BY COUNTRY
1996



150,000 METRIC TONS