# CHROMIUM

By John F. Papp

**Domestic survey data and tables were prepared by Micheal George, statistical assistant, and the world production tables were prepared by Ronald L. Hatch and Glenn J. Wallace, international data coordinators.**

In 1998, the U.S. chromium supply (measured in contained chromium) was 105,000 metric tons from recycled stainless steel scrap, 381,000 tons from imports, and 1.09 million metric tons from Government and industry stocks. Supply distribution was 62,400 tons to exports, 986,000 tons to Government and industry stocks, and 530,000 tons to apparent consumption. Chromium apparent consumption increased by 8.8% compared with that of 1997.

The United States exported about 172,000 metric tons, gross weight, of chromium-containing materials valued at about $102 million and imported about 835,000 tons, gross weight, valued at about $421 million.

Chromium has a wide range of uses in chemicals, metals, and refractories. Its use in iron, nonferrous alloys, and steel enhances hardenability and resistance to corrosion and oxidation; production of stainless steel and nonferrous alloys are two of its more important applications. Other applications are in alloy steel, catalysts, leather processing, pigments, plating of metals, refractories, and surface treatments.

Chromium is an essential trace element for human health. Some chromium compounds, however, are acutely toxic, chronically toxic, and/or carcinogenic. The U.S. Environmental Protection Agency (USEPA) regulates chromium releases into the environment. The Occupational Safety and Health Administration (OSHA) regulates workplace exposure.

Because the United States has no chromite ore reserves and a small reserve base, domestic supply has been a concern during every national military emergency since World War I. World chromite resources, mining capacity, and ferrochromium production capacity are concentrated in the Eastern Hemisphere. World chromite ore reserves are more than adequate to meet anticipated world demand. In recognition of the vulnerability of long supply routes during a military emergency, chromium was held in the National Defense Stockpile (NDS) in various forms, including chromite ore, chromium ferroalloys, and chromium metal. As a result of improved national security, stockpile goals have been reduced, and inventory is being sold. Recycling is the only domestic supply source of chromium.

The U.S. Geological Survey (USGS) has conducted mineral-resource surveys of the United States to assess the potential for occurrences of chromium and other mineral resources. The National Aeronautics and Space Administration, the National Institute of Standards and Technology, the U.S. Department of Defense, and the U.S. Department of Energy conduct alternative materials research.

### Domestic Data Coverage

Domestic data coverage of the primary consuming industries—chemical, metallurgical, and refractory—are developed by the USGS by means of the voluntary monthly Chromite Ores and Chromium Products survey.

### Legislation and Government Programs

The Defense Logistics Agency (DLA) disposed of chromium materials under its fiscal year 1998 (October 1, 1997, through September 30, 1998) Annual Materials Plan (AMP). The DLA's fiscal year 1998 AMP (as revised in April) set maximum disposal goals for chromium materials at 227,000 tons of metallurgical-grade chromite ore, 90,700 tons each of chemical-grade chromite ore and refractory-grade chromite ore, and 45,400 tons of chromium ferroalloys. The DLA also developed its fiscal year 1999 AMP, which set maximum disposal goals at 227,000 tons of metallurgical-grade chromite ore, 90,700 tons each of chemical-grade chromite ore and refractory-grade chromite ore, and 22,700 tons of chromium ferroalloy. At the end of 1998, the NDS held 1.87 million tons of chromium material comprising 974,000 tons of chromium ferroalloys, 885,000 tons of chromite ore, and 7,720 tons of chromium metal. (See table 6.)

The USEPA announced treatment standards for metal wastes destined for land disposal. It set a treatment standard for chromium wastes (D007) of 0.60 milligram per liter measured by toxicity characteristic leaching procedure (U.S. Environmental Protection Agency, 1998b).

The USEPA announced recommended water-quality criteria and described the process by which the quality standards were to be selected. The maximum recommended concentration of trivalent chromium compounds in freshwater was 570 micrograms per liter, and continuous concentration, 74 micrograms per liter. The maximum recommended concentration of hexavalent chromium compounds in freshwater was 16 micrograms per liter, and continuous concentration, 11 micrograms per liter (U.S. Environmental Protection Agency, 1998d).

The USEPA announced proposed national effluent limitation guidelines and pretreatment standards for wastewater discharges from stand-alone landfills. The maximum recommended concentration of trivalent chromium compounds in freshwater was 570 micrograms per liter, and continuous concentration, 74 micrograms per liter. The maximum recommended concentration of hexavalent chromium compounds in freshwater was 16 micrograms per liter, and continuous concentration, 11 micrograms per liter (U.S. Environmental Protection Agency, 1998a).

The USEPA required community water systems to prepare annual water-quality reports and to provide them to their customers. The reports were required to contain information about chromium, a regulated contaminant (U.S. Environmental Protection Agency, 1998c).

The U.S. Department of Health and Human Services (1998) announced food additive regulations on chromium oxide green. It permitted the use chromium oxide green pigment in polymers used in contact with food at a level not to exceed 5% by weight of the polymer except for olefin polymers and repeat-use rubber articles, which must meet other criteria.

**Production**

The major marketplace chromium materials are chromite ore and chromium chemicals, ferroalloys, and metal. In 1998, the United States produced chromium chemicals, ferroalloys, and metal, but no chromite ore. Domestic data for chromium materials are derived by the USGS from two surveys—Chromite Ores and Chromium Products (consumers, monthly) and Consolidated Consumers Survey (consumers, monthly).

Macalloy Corp. stopped electric furnace production of high-carbon ferrochromium at its Charleston, SC, plant. Macalloy had been the sole producer of high-carbon ferrochromium in North America. Ferrochromium has been produced since 1941 at the Charleston plant site, which had been constructed as part of the U.S. World War II mobilization effort and located to take advantage of access to ocean-going transportation and electrical power. Electrical power was supplied by the Santee Cooper Project, a public power supply development project in the area. The Pinopolis powerplant, a part of the Santee Cooper Project, started to supply electrical power to Pittsburgh Metallurgical Corp. in February 1942. Pittsburgh Metallurgical manufactured ferrochromium, a key ingredient in armor plating for tanks and ships.

Since 1941, the Charleston plant has been operated under a variety of names, in chronological order, including Airco Alloys Division, Air Reduction Co., Inc.; Airco Alloys and Carbide Division, Air Reduction Co., Inc.; Airco Alloys, Air Reduction Co., Inc.; and Airco Alloys, Airco Inc. It has operated as Macalloy Corp. since 1980. When Macalloy took over the plant, 8 chromium ferroalloy producers in the United States operated 12 plants.

Macalloy was negotiating with the USEPA and the South Carolina Department of Health and Environmental Control regarding remediation and cleanup at the plant site. Stormwater runs off the plant site into Shipyard Creek and adjacent marsh areas. The creek was closed to shell fishing in April owing to the high chromium levels found in crabs, oysters, and shrimps. Remediation planning was continuing at year end.

Elkem ASA (Norway) planned to sell Elkem Metals Co.'s plant at Marietta, OH, to Eramet (France), a vertically integrated manganese ore and ferromanganese producer. Elkem was pressured to sell when Broken Hill Proprietary Pty. Co. Ltd. in Australia, its manganese ore supplier, was purchased by Billiton Plc. (United Kingdom), the owner of Elkem's competitor, Samancor Limited (South Africa), also a vertically integrated ferromanganese producer. The sale was to be completed in 1999. Elkem was the sole producer of low-carbon ferrochromium in the United States and of chromium metal in the Western world using the electrolytic deposition process.

**Environment**

The Development Manager, Chrome Alloys Division, Samancor, reported on the generation and use of products associated with what had been ferrochromium production waste (Gericke, 1998). Samancor's annual solid waste generation amounted to 1.5 million tons of charge-grade high-carbon ferrochromium (ChCr) slag, 50,000 tons of low-carbon ferrochromium (LCFeCr) slag, and 18,000 tons of medium-carbon ferrochromium (MCFeCr) slag. The company classified and characterized ferrochromium production waste and then searched for uses for those materials. Waste was classified as ChCr slag, scrubber slurry, or filter dust; LCFeCr slag or dust; or MCFeCr scrubber slurry. The materials were characterized according to USEPA Toxicity Leach Procedure Tests (US EPA TLPT). ChCr filter dust and LCFeCr dust did not meet the US EPA TLPT limits for chromium. Applications developed and tested for ChCr slag included construction, fired clay bricks, and blasting grist; for LCFeCr slag and dust, cement extenders; and for LCFeCr slag, soil conditioner for acidic soils.

**Health and Nutrition**

Chromium is an essential nutrient required for sugar and fat metabolism. Normal dietary intake of chromium for humans is suboptimal. The estimated safe and adequate daily dietary intake of chromium ranges from 50 to 200 micrograms. Most diets, however, contain less than 60% of the minimum suggested intake of 50 micrograms per day. Insufficient dietary intake of chromium leads to signs and symptoms that are similar to those observed for diabetes and cardiovascular diseases. Supplemental chromium given to people with impaired glucose tolerance or diabetes leads to improved blood glucose, insulin, and lipid variables. Chromium has also been shown to improve lean body mass in humans and swine. Response to chromium is dependent upon the form and amount of the supplemental chromium, which will be of benefit only to those who are marginally or overtly chromium deficient. Trivalent chromium has a very large safety range, and signs of chromium toxicity have not been documented in any of the nutritional studies at levels up to 1 milligram per day (Anderson, 1997a).

Chromium is an essential nutrient involved in the regulation of carbohydrate and lipid metabolism. In addition to its effects on glucose, insulin, and lipid metabolism, chromium has been reported to increase lean body mass and to decrease percentage body fat, which may lead to weight loss in humans. The effects of chromium on body composition are controversial. A subject's response to chromium depends on his or her chromium status, diet, and type and amount of supplemental chromium and the duration of the study. No negative effects of dietary supplemental chromium have been confirmed in nutritional studies. If present, chromium effects will be small compared with those of exercise and a well-balanced diet (Anderson, 1998b). Insufficient dietary chromium intake by humans is prevalent. Improved dietary chromium intake leads to improved glucose, insulin, immune, and lipid responses. Effects of supplemental chromium have not been detrimental in any of the chromium nutrition studies (Anderson, 1998c).

The response to chromium supplementation for glucose, insulin, lipids, and related variables is related to the amount and form of supplemental chromium, the degree of glucose intolerance, and the duration of the study. Response to chromium is also related to stress, and beneficial effects are greater under physical or dietary stresses. Also, response to supplemental chromium is related not only to dietary chromium intake, but to the types of diets consumed because some dietary components, such as simple sugars, increase chromium losses (Anderson, 1998a).

The safety of chromium as a nutrient supplement was studied by feeding chromium chloride and chromium picolinate to rats. Data demonstrate a lack of toxicity of trivalent chromium at levels that are, on a per-kilogram basis, several thousand times the upper limit of the estimated safe and adequate daily dietary intake for humans. Animals consuming the picolinate-supplemented diets had several-fold higher chromium concentrations in the liver and kidney than those fed chromium chloride (Anderson, 1997b).

## World Review

In 1998, the chromium industry underwent a major restructuring transition. South African ferrochromium production, approaching 1.5 million metric tons per year, accounted for about 30% of world production and exceeded that of the second largest producer nation by a factor of about 3. South African annual ferrochromium production capacity was about 2.5 million metric tons, gross weight, distributed among the following companies, in million tons, gross weight: Samancor, 1.3; Chromecorp (Pty.) Ltd., 0.6; Consolidated Metallurgical Industries Limited (CMI), 0.4; Feralloys Ltd. and Hernic Ferrochrome (Pty.) Ltd., 0.1 each. Südelektra Holdings AG (Switzerland), owner of Chromcorp, increased its production capacity to nearly that of Samancor through its purchase of CMI. (See South Africa below.)

***Industry Structure***.—The chromium industry comprises primarily chromite ore (table 13), ferrochromium (table 14), and stainless steel producers. Other industry components are chromite refractory and chromium chemical and metal producers. The trend toward vertical integration was evident within and across national boundaries. Brazil, Finland, India, Japan, Kazakhstan, South Africa, Turkey, and Zimbabwe are countries that have a vertically integrated chromium industry. By vertically integrated, I mean that at least two of the three major industry sectors, chromite ore mining, ferrochromium production, and stainless steel production, are owned by a single company. The list presented above is in alphabetical order because it is policy of the USGS to present lists in alphabetical order or explain the reason for the order of the list. The discussion below in not in alphabetical order. The order is first to discuss the greatest extent of integration, i.e., those cases where all three major industry sectors are covered by one owner, followed by cases were two of the major industry sectors are under one owner; first mining and ferrochromium production, then ferrochromium and stainless steel production.

In Finland, Outokumpu Oy, a major share of which is state-owned, owned and operated chromite mining and ferrochromium and stainless steel production facilities, making it completely vertically integrated.

In South Africa, chromium-related companies are privately owned. Typically, major shares of a company are owned by other companies, and the remainder, if any, are openly traded. Samancor owned and operated chromite mining and ferrochromium production and co-owned major stainless steel production facilities. Suedelecktra owned and operated chromite mining and ferrochromium production facilities. Bayer AG (Germany) owned a chromite mining and a chromium chemical production facilities.

In India, major ferrochromium plants were licensed and small plants were not. Many small ferrochromium and chromium chemical plants operated. Ferro Alloys Corp. Ltd. (Facor) was integrated from chromite ore mining through ferrochromium and stainless steel production. Jindal Alloys was integrated from ferrochromium production through stainless steel production. Indian Charge Chrome Ltd. and The Tata Iron and Steel Company were each vertically integrated from chromite ore mining through ferrochromium production. In addition to these large, vertically integrated companies, the Indian chromium industry comprised other large and small producers. About 20 chromite mines produced ore.

In Brazil, the mining and smelting of chromium was vertically integrated, but stainless steel production was independent of the mining-smelting operations. Cia. de Ferro Ligas da Bahia owned an operated chromite ore mining and ferrochromium production facilities. Stainless steel was produced primarily by Companhia Acos Especiais Itabira. Refractory chromite operations are also vertically integrated from chromite production through refractory material production.

In Japan, chromite ore mining was independently owned, of small size, and primarily for refractory industry use; however, ferrochromium producers were associated with stainless steel plants by location or ownership or both. Nippon Steel, Nisshin Steel, NKK, and Pacific Metals produced ferrochromium and stainless steel or had ferrochromium production colocated with stainless steel plants.

In Kazakhstan, chromite ore mining and ferrochromium production was vertically integrated.

In Turkey, the chromium industry comprised large and small chromite ore producers, with one major producer, Etibank General Management, integrated from mining through ferrochromium production.

The chromium industry of Zimbabwe comprised large companies vertically integrated from chromite ore mining through ferrochromium production, small independent chromite mines, and chromite mines operated independently on behalf of the large vertically integrated companies. Both Zimasco and Zimbabwe Alloys owned and operated chromite mines and ferrochromium plants.

Elkem integrated its high-carbon ferrochromium production across international boundaries by using chromite ore from a Brazilian mine that it owns to feed its Norwegian smelter.

***Capacity***.—Rated capacity is defined as the maximum quantity of product that can be produced in a period of time at a normally sustainable long-term operating rate on the basis of the physical equipment of the plant and given acceptable routine operating procedures involving energy, labor, maintenance, and materials. Capacity includes operating plants and plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure. Because not all countries or companies make production capacity information available, historical chromium trade data have been used to estimate production capacity. Production capacity changes result from changes in facilities and in knowledge about facilities. Countries have been rated for production capacities of chromite ore, chromium chemical, chromium metal, and ferrochromium industries. (See table 17.)

***Reserves***.—The United States has no chromite ore reserves, but it does have a reserve base and resources that could be exploited. In 1998, the U.S. reserve base was estimated to be about 10 million tons of chromium, the world reserves were about 3.6 billion tons, and the reserve base was about 7.5 billion tons. More than 80% of world reserves and more than 70% of the world reserve base were located in South Africa (Papp, 1999).

***Production***.—In 1998, world chromite ore production was estimated to be about 12.7 million tons, a 5% decrease compared with that of 1997 (table 15). World ferrochromium production was estimated to be about 4.9 million tons, a 2% increase over that of 1997 (table 16). World production of ferrochromium-silicon was small compared with that of ferrochromium.

***Albania.—***The Government accepted an offer from Kinglor (Italy) and Reconstruction & Development International (United Kingdom) to renovate the chromium industry. The consortium proposed to modernize the Buluqiza and the Kalimash Mines and to develop the ferrochromium smelters and hydroelectric power. Privatization of Albkrom, the Government-owned chromite and ferrochromium producer, and foreign investment in Albania's chromium industry continued throughout 1998 (Metal Bulletin, 1997, 1998b,r; Ryan's Notes, 1998c).

***Australia.—***Danelagh Resources Pty. Ltd. produced chromite at the Coobina chromite deposit 57 kilometers east-southeast of Newman, Western Australia. In 1998, Danelagh had an option to buy a 70% share from Valiant Consolidated Limited, which changed its name to Consolidated Minerals Ltd. in April. The Coobina Range consists of a central core of serpentine. An associated gabbro was formed by the serpentinisation of layered peridotite, which contains minor amounts of carbonate, chlorite, chromite, magnetite, and talc. As of December 1997, resources were measured, 39,000 tons graded at 38.5% chromic oxide; indicated, 86,200 tons graded at 39.7% chromic oxide; and inferred, 400,000 tons of similar grade. The mining process used is open cut, and run-of-mine ore is crushed and screened. In 1995, Danelagh agreed to mine, remove, and sell 200,000 tons of chromite ore for which it would pay a royalty to Valiant or purchase 70% equity. Trial mining continued in 1998. Chromite ore exported in 1997 graded 40% to 41% chromic oxide (39% guaranteed) with chromium-to-iron ratio in the range of 1.55 to 1.6 (Resource Information Unit, 1998a, p. 309; b, p. 407).

Dragon Mining NL studied the Range Well deposit 67 kilometers northwest of Cue, Western Australia. Chromium occurs predominantly in the iron oxide minerals hematite and goethite. The Range Well laterite resource lies directly over part of a 5.5-kilometer-thick funnel-shaped layered ultramafic complex. The inferred resource was estimated to be 31 million tons graded at 3.6% chromium (2% cut-off grade) (Resource Information Unit, 1998a, p. 309).

***Brazil.—***Brazil produced chromite ore for use in the metallurgical and refractory industries. Production in 1997 was reported to have been 300,000 tons of chromite ore containing 112,000 tons of $Cr_2O_3$, of which 95% was used for ferrochromium production, 4% was for chemicals, and 1% for refractories, and 112,274 tons of ferrochromium. Chromite ore (measured in contained $Cr_2O_3$) exports were 43,500 tons; imports, 5,728 tons. Ferrochromium and metal exports were 16,300 tons; imports, 6,941 tons. On the basis of production and trade of chromite ore and trade of ferrochromium, 1997 chromium apparent consumption in Brazil was 45,800 tons, contained chromium (Cesar, 1998).

Cia. de Ferro Ligas da Bahia purchased the Coitezeiro Mineração chromite mine from Bayer AG. Bayer planned to transfer chromium chemical production from its Brazilian plant to its Argentinean plant and to supply the plant with chromite ore from South Africa.

***Canada.—***Natural Resources Canada reported chromium material trade for 1995 and consumption for 1994. Imports were 62,707 tons of ferrochromium, 36,991 tons of chromite ore (13,292 tons refractory grade, 23,699 tons not refractory grade), and 365 tons of chromium metal. Consumption was 48,278 tons of ferrochromium and 9,843 tons of chromite ore. (Louis Perron [1996], Chromium, Canadian Minerals Yearbook 1995, accessed May 3, 1999, at URL http://www.nrcan.gc.ca/ mms/cmy/CMY_E3.html).

Dow Corning Corp. sold its smelter at Selkirk, Manitoba, to Manitoba Hydro, the local power company. Gossan Chrome Corp., a subsidiary of Gossan Resources Ltd., leased an unused electric furnace at Selkirk, Manitoba, for the production of chromium-nickel master alloys. Gossan took a 15-year renewable lease with the option to purchase. The company planned to convert a 6-megavolt-ampere furnace to a 9-megavolt-ampere furnace at a cost of Can$10 million to produce 17,000 tons per year of chromium-nickel alloys. The smelter is 20 miles north of Winnipeg. Smelter renovation cost was estimated to be Can$8 million to Can$10 million. Gossan owned the Lac Du Bonnet chromite deposit near the smelter. The deposit was estimated to be able to produce 30,000 tons of chromite graded at 27% chromic oxide for 23 years (Metal

Bulletin, 1998j, k; Ryan's Notes, 1998d).

Cancor Mines Inc. and Coleraine Mining Resources Inc. announced an agreement in principle with Procoloro Resources Inc. that permitted Procoloro to purchase chromium assets pooled by Coleraine and Cancor for $2.5 million. These assets include the Coleraine, the Garthby, the Lac Montjoie, the Reed-Belanger, and the Sterret properties which are located in the Thetford area of Quebec. The two major deposits are the Coleraine, which has proven and probable reserves of 1.2 million tons containing 4% chromic oxide, and the Reed-Belanger, which has reserves of 6.2 million tons containing 7.19% chromic oxide. Shipping grade production could reach 48,000 tons per year graded at 48% chromic oxide. Combined proven reserves were 7.4 million tons; of that, 1.2 million graded at 4% to 4.5% chromic oxide was accessible by open pit mining, and the remaining 6.2 million tons was graded at 7.19% chromic oxide. Procoloro planned a smelter to produce ferrochromium containing 60% to 64% chromium at a production cost of Can$0.29 per pound of contained chromium. An estimated 2 tons of chromite ore concentrate would be required to produce 1 ton of ferrochromium. The agreement was to be completed within a 3-year period after signing the agreement (Metal Bulletin, 1998p; Platt's Metals Week, 1998a; Bruce Lipin, U.S. Geological Survey, written commun., June 9, 1998).

***China.***—In its national chromium-material trade statistics for 1998, China reported chromite ore imports of 711,539 tons compared with 893,987 tons in 1997 and 764,147 tons in 1996. During this time, the average value of chromite ore measured in dollars per ton, gross weight, dropped to $110.00 in 1998 from $123.90 in 1997 and $163.90 in 1996. Because most Chinese ferroalloy plants have small electric furnaces and no chromite-ore-presmelting-treatment facilities, this material was either stockpiled or converted to ferrochromium mostly for export. In 1998, high-carbon ferrochromium exports totaled 65,538 tons valued at $40.7 per ton, gross weight, compared with 70,848 tons valued at $43.6 per ton, gross weight, in 1997. Low-carbon ferrochromium exports totaled 36,487 tons valued at $69.4 per ton compared with 27,222 tons valued at $79.6 per ton in 1997 (TEX Report, 1999g, h).

About 40% of chromite ore reserves and production were in the autonomous region of Tibet. As part of its program to emphasize mining in Tibet, China planned to develop chromite mining. Exploration for chromite occurred in Dongqiao, Lake Qieli along the Lake Bangong-Nujiang River fault belt and in the Luobusha fault belt, and Yilashan (Mining Journal, 1998c).

China was considering the possibility of merging Jilin Ferroalloy Works , Liaoyang Ferroalloy Group Corp., and Jinzhou Ferro-Alloy (Group) Co. Ltd., all of which are in the northeast. The Sichuan Provincial Government reorganized the Emei Ferroalloy Joint-Stock Co. Ltd. and its associated companies into the Sichuan Chuanton Emei Ferroalloy Group Co. Ltd., took over management of Changcheng Special Steel Corp. Ltd., and planned to take over the Jia Yang Power Station, which would then supply power to the Group. This reorganization was made in support of the Chinese Government's policy to strengthen and reinforce key industries by consolidating them (TEX Report, 1998c, d).

Chinese stainless steel production was reported to have been 300,000 tons in 1995. China planned to expand its stainless steel production capacity in line with its domestic demand, which was 700,000 tons in 1998. Assuming growth between 5% and 6%, China anticipated a demand of 1.5 million tons, 0.79 kilograms per capita, by 2010. Ningbo Baoxin Stainless Steel Plant in Zhejiang Province and Zhangjiagang Stainless Steel Plant in Jiangsu Province were recently completed. Taiyuan Iron and Steel Company in Shanxi Province, with an annual stainless steel production capacity of 400,000 tons, and Pudong Iron and Steel Plant in Shanghai, with an annual stainless steel production capacity of 440,000 tons, were two more projects anticipated to be completed after 2000 (Metal Bulletin, 1998d).

According to an analysis of the ferroalloy industry of China, China has tried to be self-sufficient in ferroalloy production (Dai, 1999). State-owned enterprises dominated low-carbon ferrochromium production, and small ferroalloy plants dominated high-carbon ferrochromium production. The cost structure of low-carbon ferrochromium was as follows: ore cost, 41%; electricity cost, 31%; and labor cost, 4%. The cost structure of high-carbon ferrochromium was as follows: ore cost, 58%; electricity cost, 27%; and labor cost, 2%. Electrical power supply capacity did not limit ferrochromium production; electrical power tariffs, however, were a critical factor. A problem for producers was insufficient working capital. Pollution control regulations, introduced in 1998, discourage construction of furnaces of less than 3-megavolt-ampere electrical transformer capacity and called for the closure of furnaces lacking pollution control devices by 2001.

***Finland.***—Outokumpu planned to increase its chromite mine, ferrochromium smelter, and stainless steel production capacities. Plans were to approximately double the production capacity of the integrated chromium operations as market demand permits—chromite mining, from 1.1 million tons to about 2 million tons; ferrochromium, from 250,000 tons to about 500,000 tons; and stainless steel slab, from 540,000 tons to 1.2 million tons. Outokumpu reported production as 231,000 tons of high-carbon ferrochromium in 1998 compared with 237,000 tons in 1997 and 575,000 tons of stainless steel slab in 1998 compared with 544,000 tons in 1997. Outokumpu produces ferrochromium by a system of its own design wherein mining, milling, pelletizing, sintering, and smelting are engineered together. The Kemi Mine stopped production of chemical- and foundry-grade chromite ore to focus on the production of metallurgical-grade concentrates comprising upgraded lumpy and fine concentrate (Industrial Minerals, 1998c; Mining Journal, 1998b; Outokumpu Oy, 1998, p. 15).

Outokumpu reported the sale of its new pelletizing, sintering, and preheating process to Hernic Ferrochrome (South Africa) (Platt's Metals Week, 1998b).

***France.***—Delachaux SA produced chromium metal at its plant in Valenciennes for the production of superalloys and aluminum alloys.

***Germany.***—Metallurg Inc. produced low-carbon ferrochromium at its subsidiary Elektrowerk Weisweiler GmbH in Nürnberg.

***India.***—The USEPA shared technical engineering information about chromium recovery from tannery wastes with the Tamil Nadu Pollution Control Board and the Central Leather Research Institute. The chromium residue in effluents currently (1998) escapes treatment facilities available in the country and has been a major problem for the industry and monitoring agencies (Chemical Weekly, 1998).

Ferrochromium producers in Orissa State petitioned the Federal Government to reduce power rates from the current 315 paise per kilowatt-hour. Producers estimated that 140 paise per kilowatt-hour would permit a viable ferrochromium industry. Orissa ferrochromium producers included Facor, Ispat Alloys Ltd., The Tata Iron and Steel Co. Ltd., and Nava Bharat Ferro Alloys Ltd. These companies exported about 150,000 tons of ferrochromium. Producers proposed a two-tier price system wherein the export companies would get a lower price (Metal Bulletin, 1998n).

When the Orissa State Government redistributed 855 hectares of chromite ore resources formerly held by Ferro Alloys Corp., it retained 437 hectares and distributed 418 hectares as follows: Indian Charge Chrome Ltd. and Indian Metals and Ferro Alloys Ltd., 190 hectares, 43 million tons of reserves; Ispat Alloys, 100 hectares, 10 million tons; Jindal Strips Ltd., 89 hectares, 9 million tons; and Ferro Alloys Corp. Ltd., 39 hectares, 4 million tons. Ferro Alloys Corp. challenged a decision by the Government of Orissa to contract Indian Charge Chrome and Indian Metals and Ferro Alloys as mining agent for its resources (Metal Bulletin, 1998i).

Nava Bharat converted chromite ore to ferrochromium for Tata. It was expanding its captive 30-megawatt powerplant to 50 megawatts and had plans to expand the powerplant to 110 megawatts (Metal Bulletin, 1998m).

Tata operated a chromite ore beneficiation plant at its Sukinda Mine in Orissa State. The beneficiation plant's annual production capacity was 160,000 tons; that capacity, however, was being increased to 250,000 tons per year. Tata's ferrochromium plant at Bamnipal, Orissa, had an annual high-carbon ferrochromium production capacity of 50,000 tons, which was being increased to 60,000 tons through the improvement of feed materials (TEX Report, 1998n).

Stainless steel production grew by 18% between 1980 and 1995. Per capita stainless steel consumption was about 0.6 kilogram compared with 10 to 18 kilograms in developed countries. The major stainless steel producers were Steel Authority of India and Jindal Strips. Growth of stainless steel production was expected to continue at a rate of 8% to 10% per year as the Indian economy develops (TEX Report, 1998b).

***Iran.***—Chromite ore production was cut back to 150,000 tons in 1997 so that the mining operations could recover from the high production rates of 1995 and 1996. Annual production was expected to increase to 400,000 tons. Iran also produced ferrochromium at Faryab Mining Co.'s Abadan Ferroalloys Refinery.

Iran was developing its stainless steel industry. Iron Alloy and Steel Co. contracted Danieli (Italy) and Mitsubishi Corp. (Japan) to construct a new alloy and stainless steel plant at Yazd. The plant cost was $480 million and was owned by National Iranian Steel Co. (63%) and Bank Saderat (37%). Danieli and Mitsubishi were constructing the plant using European equipment. The plant comprised two 40-ton electric-arc furnaces, two 40-ton ladle furnaces, two vacuum decarburization and vacuum-oxygen decarburization units, a two-strand caster, and an ingot casting shop. Annual steel production capacity was planned to be 140,000 tons and to be increased to 220,000 tons (Metal Bulletin, 1998e; TEX Report, 1998h).

***Italy.***—Per capita stainless steel consumption rose to 16.5 kilograms in 1997 from 1.3 kilograms in 1965, a compounded annual growth rate of 8.3% compared with 2.6% for steel. Stainless steel production reached 1.033 million tons in 1997. About three-fourths of production was austenitic grade. Stainless steel consumption by industry sector was as follows: food industry, 20%; chemicals and petrochemicals, 20%; household appliances, 18%; catering, 12%; transportation, 8%; housing, 5%; energy, 5%; pharmaceutical industry, 4%; and others, 6%. Acciai Speciali Terni, a privately owned company since 1994, was the major stainless steel producer; its plant was in Terni (Fumagalli, 1998).

***Japan.***— Japan levied a 5.8% ad valorem import duty on ferrochromium in 1998 and planned to lower that duty to 5.3% in 1999 in accordance with the Uruguay Round of tariff agreements made in 1995. The country imported 416,665 tons of chromite ore, 628,260 tons of ferrochromium, and 2,327 tons of chromium metal. Domestically, the Japan Ferroalloy Association reported that the ferroalloy industry produced 105,634 tons of ferrochromium, a decrease of 47% compared with that of 1997. Stainless steel production was 3.102 million tons—hot rolled stainless steel, 2.767 million tons, and heat-resisting, 334,150 tons. Japan exported 1.140 million tons of stainless steel, representing 37% of production, and 700 tons of ferrochromium. Japan imported 144,143 tons and exported to 22,943 tons of stainless steel scrap. On the basis of chromite ore, chromium metal, and ferrochromium trade, chromium apparent consumption in Japan was 473,000 tons of contained chromium (TEX Report, 1998g, 1999a, b, c, d, e, f, i, j; Platt's Metals Week, 1999).

Compared with 1997 statistics, Japan's ferrochromium production, chromium apparent consumption, and stainless steel production decreased by about 47%, 23%, and 15%, respectively. The ferrochromium import market share rose to 86%, which is part of a long-term trend of declining domestic production. Chromium metal imports rose by a factor of about 20, which indicates that stocks from Tosoh Corp., the former domestic producer, have run out and that Japan has turned to external supply sources to meet domestic demand. The export market share of stainless steel production rose, reflecting reduced demand resulting from the Asian economic crisis.

***Kazakhstan.***—Donskoy Ore Dressing Complex operated three mines. Donskoy produced 1.6 million tons in 1998 and 1.8 million tons in 1997 from 316 million tons of reserves and an additional 1 billion tons of resources. The open pit mine was being depleted of reserves, so shafts were being developed for underground mining. Donskoy reported having a stockpile of about 1 million tons of fines. The fines had a minimum $Cr_2O_3$ content of 42% and typical content of 44% to 45%, a chromium-to-iron ratio of 2.8, and sizes up to 10 millimeters. Donskoy studied the possibility of installing a sintering plant.

About 5% of shipments were for chemical or refractory users in the Confederation of Independent States (Metal Bulletin, 1998a; Ryan's Notes, 1998b; Industrial Minerals, 1999e; Vilppula, 1999).

Aksusky Ferroalloy Plant (Aksu) produced high-carbon ferrochromium and other ferroalloys. Aksu chromium ferroalloy annual production capacity was about 400,000 tons of high-carbon ferrochromium and 60,000 tons of low-carbon ferrochromium. Aktyubinsk Ferroalloys Plant produced chromium metal, high-, medium-, and low-carbon ferrochromium, and other ferroalloys. Aktyubinsk chromium ferroalloy annual production capacity was 240,000 tons of high-carbon ferrochromium, 24,000 tons of medium-carbon ferrochromium, and 25,000 tons of low-carbon ferrochromium. All chromite ore was from Donskoy. Chromium metal, a new product, was graded at between 98.3% and 99.3% chromium. Production was to proceed when demand was apparent (Metal Bulletin, 1998o; Vilppula, 1999).

***Korea, Republic of.*****—**Ferrochromium imports were 224,529 tons, and consumption was 243,527 tons (TEX Report, 1999k).

***Macedonia.*****—**Although Jugochrom continued operation as a ferroalloy producer, it discontinued low-carbon ferrochromium production in 1997 and has not resumed. Jugochrom exported through Greece. The Radusa chromite mine near Skopje continued chromite ore production. The ferrochromium plant is 30 kilometers from Kosovo (Metal Bulletin, 1999d; Walter Steblez, U.S. Geological Survey, oral commun., 1999).

***Madagascar.*****—**In 1998, Kraomita Malagasy reported chromite ore production of 140,000 tons comprising 40,000 tons of concentrates and 80,000 tons of lumpy ore from the Andriamena Mine and 20,000 tons of fines from the Behandrinana Mine. Kraomita shipped 10,000 tons of ore by rail from Morarano station and 4,000 metric tons per month by truck to the port at Toamasina. Kraomita reported chromite ore exports of 120,000 tons in 1998 (TEX Report, 1998l).

***Norway.*****—**Elkem produced high-carbon ferrochromium containing 60% to 65% chromium from two closed furnaces at its ferrochromium plant in Rana. Annual high-carbon ferrochromium production was 170,000 tons in 1998 and 148,000 tons in 1997 (Elkem ASA, 1999, p, 50-51; Ryan's Notes, 1999b, d).

***Pakistan.*****—**Of the four chromite mining areas, three are in Baluchistan Province (Kharan, Muslim Bagh, and Wad), and one is in Frontier Province. Since the Pakistan Chrome Mines Ltd.'s leases lapsed in 1995, chromite mines in these areas have been operated by small contractors owned by local districts. They supply chromite to the exporters. Syndicated Mines & Minerals Company and Zhob Valley Minerals Company exported chromite (Industrial Minerals, 1998a, 1999d).

***Romania.*****—**S.C. Ferom S.A., the ferroalloy producer in Tulcea, stopped ferrochromium production in November. The company reportedly had large debts that it could not pay, so the local court put it under receivership (Metal Bulletin, 1999c, d).

***Russia*****.**—Dissolution of the Soviet Union impacted chromium demand in Russia. Chromium metal demand dropped to 450 tons in 1998 from 850 tons in 1995 and 9,700 tons in 1989. Severonickel carried out prospecting of the Sopcheozero chromite deposit. This deposit is located on the Kola Peninsula about 30 kilometers from the Severonickel plant site. Exploration work since 1990 showed that the plate-shaped deposit is 24 meters thick, extends 2 kilometers to the southeast, ranges from 16 to 300 meters in depth, has a chromic oxide content in the range of 10% to 49% with average ore grade of 26%, and has 5.5 million tons of reserves and an additional 10 million to 15 million tons of resources. The mine was expected to start as an open pit and then move to underground mining with annual production of 50,000 tons. Processing was expected to yield chromite ore product graded up to 49% with a chromium-to-iron ratio of less than or equal to 3.2. Severonickel planned to mine associated olivine (a magnesium oxide mineral) for refractory use (Galkin, 1999; Saretski, 1999; Russian Joint-Stock Company Norilsk Nickel, Severonickel celebrates its 60$^{th}$ birthday, accessed April 12, 1999, at http://www.nornik.ru/index.html/english/press/pr/030399.html).

Chelyabinsk Electrometallurgical Integrated Plant produced low-carbon ferrochromium. Klutchevsk Ferroalloy Plant produced chromium metal and made a wide variety of alloys used for alloying heat-resistant steels, including aluminothermic chromium metal, high- and low-carbon ferrochromium, and many other alloys (Metal Bulletin, 1998c; Ryan's Notes, 1998a; Saretski, 1999).

The stainless steel industry in Russia was small but active. Most of the historical production was oriented to military applications that were generating about 15,000 tons per year of stainless steel scrap. Annual domestic production was estimated to be 35,000 tons, and consumption was estimated to be 80,000 tons. Major western suppliers were Russia's nearest neighbors—Finland, Germany, Sweden, and the United Kingdom. Domestic stainless steel producers included Mechel in Chelyabinsk, Severstal in Cherepovets, Izhovstal in Izhevsk, and Krasny Oktiabr in Volgograd, a company that was reorganizing (Pirie, 1998; Terlovoy, 1999).

***South Africa*****.**—The South Africa Department of Minerals and Energy reported mineral production. In 1997, South Africa produced 5.74 million tons of chromite ore, of which 1.27 million tons was exported. In the same year, chromium ferroalloy production was 1.89 million tons, of which 1.75 million tons was exported (E.S. Bates, Chromium Chapter, South Africa's Minerals Industry 1997/98, accessed June 17, 1999, at http://www.dme.gov.za/minerals/mod97.htm).

An analysis of the South African chromium industry showed that South Africa remained a major ferrochromium producer because the region was competitive, that reserves of chromite ore and reductants were ample, that electrical power was inexpensive, and that labor cost was competitive. Of world chromite ore reserves, 70% was in the Bushveld Igneous Complex in South Africa. The ore has been mined by open pit mining, which requires less capital investment than underground mining. As these shallow reserves are depleted, more costly underground mining will have to be developed. Ferrochromium production is an electrical-energy-intensive process that requires between 2,800 and 4,800 kilowatt-hours per metric ton of product. South African electrical power cost was low relative to world prices. Chromite ore cost was estimated to have been between $10 and $30 per ton delivered to the ferrochromium plant. Transportation cost was estimated to have been $0.02 to $0.03 per pound for overland transport from plant to port and $0.04 to $0.05 per pound for delivery from port to consumer. Labor productivity was good and increasing faster than labor cost (van der Walt, 1998).

Ferrochromium production approached 1.5 million tons per year, accounting for about 30% of world production and exceeding that of the second largest producer nation by a factor of about 3. Annual ferrochromium production capacity was about 2.5 million tons, gross weight, distributed among the following companies, in million tons, gross weight: Samancor, 1.3; Chromecorp (Pty.) Ltd., 0.6; CMI, 0.4; Ferroalloys and Hernic, 0.1 each. Südelektra Holdings AG, the world's second largest ferrochromium producer, nearly doubled its production capacity through its purchase of CMI. It already owned Chromecorp Holdings (Pty.) Ltd., thus forming the second largest ferrochromium-producing company by consolidating ownership of South Africa's second and third largest producers. Billiton Plc. owned 52.6% of Samancor, which remained the largest ferrochromium producer, but, Südelektra, its largest competitor was of comparable size. (See Ferrochromium below.)

**Chromium Chemicals.—**Chrome International Company, a joint venture between Bayer (Pty.) Ltd., a subsidiary of Bayer AG (Germany), and Dow Chemical Corp., constructed a chromium chemical plant at Newcastle, KwaZulu-Natal Province, at a cost of about $133 million. Production started in May with the expectation of reaching full capacity in 1999. The plant was expected to require about 100,000 tons per year of chromite ore from Bayer's chromite mine near Rustenburg. Bayer produced chromium-containing tanning salts at its Merebank plant, which is 20 kilometers from Durban and has a rail siding that it uses to transport materials for export through Durban. Bayer planned to export about 90% of the tanning salt produced. Annual production capacity of sodium dichromate was expected to reach 70,000 tons; chromium tanning salts, 45,000 tons; and chromic acid, 10,000 tons. Annual tanning salt production capacity was 45,000 tons. Bayer made tanning salts in Europe until tanning moved from Europe to the countries where hides were being produced; for example, Argentina, Australia, Brazil, Ethiopia, Kenya, and the United States; tanning converts the perishable hides into durable leather. About 80% of leather tanned worldwide was tanned with chromium tanning salts. About 33% of sodium dichromate production was to be used within the plant to make tanning salts. The remainder was to be shipped to Bayer's chromic oxide pigment production plant in Germany (Engineering News, 1998; European Chemical News, 1998; Industrial Minerals, 1999b).

**Chromite Ore.—**Samancor operated chromite ore mines in the eastern and western chromite ore belts. The company reported an annual marketable chromite ore production capacity of 3.63 million tons—1.99 million tons from five eastern mines and 1.64 million tons from four western mines. Samancor exploited chromite ore reveres from the LG6, MG1, and MG2 seams (Samancor Limited, 1998, p. 6, 12-14, 16-18).

At the long-term average annual world stainless steel growth rate of 3.6%, a projected 150,000 tons per year of ferrochromium would be required to make that stainless steel. To make the ferrochromium, a projected 420,000 of chromite ore would be required. Samancor studied the feasibility of developing the chromite resources between its Doornbush and Montrose sections (Mining Weekly, 1998a; Samancor Limited, 1998, p. 17).

Südelektra produced about 3.5 million tons of run-of-mine chromite ore distributed among the Thorncliffe and Chroombronne Mines with an annual chromite ore production of about 960,000 tons each; the Wonderkop Mine, 720,000 tons; the Purity Mine, 540,000 tons; and the Waterval Mine, 360,000 tons. Südelektra planned to increase production at the Thorncliffe Mine to 1 million tons because the mine exploited the LG-6 seam, which is 1.8 to 2.0 meters thick, and produced a larger fraction of lumpy ore (TEX Report, 1998e, m).

Northern Province Development Company owned Dilokong Mine near Burgersfort, Northern Province. The mine produced lump and fine chromite ore with an annual production capacity of 350,000 tons. The lump ore was sold locally to ferrochromium plants; the fine ore was exported to the foundry industry. Diversion of production to the ferrochromium smelter was planned upon completion in 1999 (Metal Bulletin, 1998g).

Associated Manganese Mines of South Africa Ltd. purchased the mineral rights to chromite on the Dwarsriver Farm property from Gold Fields of South Africa Limited for R163 million. Dwarsriver had chromite ore reserves of 40 million tons and additional resources of 200 million tons to a depth of 700 meters in the Eastern Belt. The property is near Lydenburg, Mpumalanga State. Together with Associated Ore and Metals Corp., Associated Manganese conducted a mine feasibility study. They planned to proceed with development by bringing an opencast chromite mine with an annual production capacity of 350,000 tons into production in 2000. The mine was intended to supply Feralloys ferrochromium plant at Machadodorp. Chromite ore was to be transported by truck from the mine to Steelpoort, a distance of 26 kilometers, then by rail to the smelter (Industrial Minerals, 1999a; Mining Journal, 1998a; Metal Bulletin, 1998g, h).

Chromeden (Pty.) Ltd. started open pit chromite ore mining in 1997 and planned to start underground mining in 1999. The mine, located about 20 kilometers northwest of Sun City in North-West Province, produced about 250,000 tons per year of crude ore for marketable products to the chemical, foundry, metallurgical, and refractory industries. Chromeden was a subsidiary of Transatlantic Minerals based in the Channel Islands (United Kingdom). Nicor (Pty.) Ltd. processed chromite ore under contract for Chromeden. About 95% of production was destined for export (Industrial Minerals, 1999c).

Chrome Chemicals (Pty.) Ltd. produced chromite ore with an annual production capacity of 1 million tons. About 75% of its production went to Chrome International's chromium chemicals plant; the remainder went to the ferrochromium industry (Industrial Minerals, 1999c).

**Ferrochromium.—**Samancor was the world's largest ferrochromium producer with an annual ferrochromium production capacity of about 1.249 million tons from five divisions—Batlhako Ferrochrome Ltd., Ferrometals Division, Middelburg Ferrochrome Division, Palmiet Ferrochrome Division, and Tubatse Ferrochrome Division. To meet increasing demand, Samancor improved the efficiency of it's operating plants. It financed the improvements through joint-venture partnerships with traders and consumers, thereby achieving the larger goal of improved capacity utilization. The company installed ferrochromium-from-slag recovery plants at its major ferrochromium plants and was proceeding to make production more efficient. This approach delayed the need to build new plants, although new plants will be inevitable if world stainless steel production continues to grow (Samancor Limited, 1998, p. 6, 12-14, 16-18).

Ferrometals constructed a pelletizing plant to feed three furnaces and preheating lines for two of those furnaces. These facilities, developed by Outokumpu, started operation in 1998. Pelletizing permits use of fine ore, improves chromium recovery of the smelting process (from 80% to 85%), increases furnace annual production capacity (from 85,000 to 100,000 tons for preheated and from 70,000 to 80,000 tons for cold feed), decreases unit consumption of energy (by 500 kilowatts per ton), and more closely matches chromite ore production capacity to smelter material requirements. Ferrometals planned that production at the plant would be 520,000 tons per year of pellets, which would increase the ferrochromium production capacity of existing furnaces by 60,000 tons per year owing to more-efficient smelting. This upgrading was based on a joint-venture agreement with Japan Metals and Chemicals Co. Ltd. (JMC) and Mitsui (Japan) in which JMC would displace ferrochromium production in Japan with that from Ferrometals (Platt's Metals Week, 1997; South African Mining, Gold, Coal, and Base Minerals, 1997; Calms, 1998; Ruffini, 1998).

Middelburg Ferrochrome Division reported operating its Chrome Direct Reduction process by feeding material from the kiln directly into its direct-current (DC) electric-arc furnace, thus improving energy consumption and throughput of the process. The company's metal-from-slag recovery process achieved an annual ferrochromium recovery rate of 5,700 tons. At this treatment rate, an estimated 15 years would be needed to treat its existing dump (Samancor Limited, 1998, p. 16).

Suedelektra SA, a subsidiary of Südelektra, became the world's second largest ferrochromium producer. Suedelektra produced about 900,000 tons of charge-grade high-carbon ferrochromium at four plant sites—Chrome Resources plants at Rustenburg and Wonderkop and CMI plants at Lydenburg and Rustenburg. Suedelektra's annual ferrochromium production capacity was about 1.02 million tons—400,000 tons from the Rustenburg plants, 320,000 tons from the Wonderkop plant, and 300,000 tons from the Lydenburg plant (TEX Report, 1998e, m).

ASA Metals (Pty.) Ltd., a joint venture of East Asian Metal Investment Corp. and Northern Province Development Co., started construction of an estimated R137 million ferrochromium smelter at the Dilokong chromite mine in the eastern chromite belt at Sekhukhune, Northern Province; the mine was the principal asset. East Asian Metal was a parastatal organization whose major shareholders were China Iron & Steel Industry & Trade Group Corp. and Jilin Ferroalloy Works. ASA contracted Pyromet to construct one furnace with the potential for a second furnace to be added. In July, Pyromet started construction of the furnace, which will have an annual high-carbon ferrochromium production capacity of 50,000 tons and an electrical transformer capacity of 27 megawatts. The furnace was designed to take a high fraction of fines and had a new electrode design developed by Pyromet (Metal Bulletin, 1998f, g; Mining Weekly, 1998b).

Feralloys Ltd., a subsidiary of Associated Manganese Mines of South Africa Ltd., produced charge-grade high-carbon ferrochromium at its smelter in Machadodorp, which had an annual production capacity of 146,000 tons (TEX Report, 1998a).

Hernic operated a ferrochromium smelter near Brits. The plant had an annual high-carbon ferrochromium production capacity of 130,000 tons from two semiclosed, 37-megavolt-ampere furnaces. Hernic started to upgrade the plant by adding a closed-furnace with electrical transformer capacity of 50 megawatts, a new beneficiating plant, and a pelletizing and preheating operation. The pelletizing and preheating operation was to be supplied by Outokumpu at a cost of $12.8 million and have an annual pellet output capacity of 350,000 tons. With pelletizing, Hernic would be able to use previously unusable chromite ore fines. Use of pellets permits less use of fines, resulting in greater productivity and recovery. Off-gas from the closed furnace was to be used to power the preheating operation. The new equipment was to start production in 1999. Surplus pellet production was to feed the other furnaces, thereby increasing their production capacity. In 1998, annual high-carbon ferrochromium production capacity was about 130,000 tons divided equally between two furnaces. Upon completion of the upgrades, annual high-carbon ferrochromium production capacity would be 260,000 tons. The plant employed about 250 people; that number was planned to rise by 100 with the renovations. The expansion was expected to cost about $40 million (R200 million). Hernic had marketing arrangements with Mitsui and JMC to substitute for JMC-produced ferrochromium supplied to Nippon Steel Corp. as JMC closed down its production capacity. Hernic also had a relation with Mitsubishi Corporation, which invested in the plant expansion, to market its ferrochromium in Japan. Hernic was co-owned by ELG Haniel AG, a major stainless steel scrap processor and supplier (Business Day, 1998; Metal Bulletin, 1998l; Mining Weekly, 1998c; TEX Report, 1998f, i, and j ).

***Sweden.***—Vargön Alloys AB operated three of its four ferrochromium furnaces in 1998. It planned to close its 105-megavolt-ampere furnaces temporarily in 1999 to adjust inventory (Metal Bulletin, 1999b; Ryan's Notes, 1999d, e).

***Taiwan.***—Taiwan imported 296,297 tons of high-carbon ferrochromium in 1998, an increase of 6.3% compared with that of 1997 (TEX Report, 1999l).

***Turkey.***—Dedeman Madencilik Sanayi ve Ticaret A.S. reported production of about 110,000 tons of chromite ore in 1998 compared with 120,000 tons in 1997. Kromsan, a sodium dichromate producer in Mersin, was constructing a chromic acid production plant at the same location. Chromic acid is produced from sodium dichromate. The plant was to have an annual chromic acid production capacity of 6,000 tons

(Industrial Minerals, 1998b; Metal Bulletin, 1998q; Sisecam, 1998, '97 Annual Report, accessed January 19, 1999, at http://www.sisecam.com/eng/annual7.htm).

***United Kingdom.—***Elementis UK Limited produced sodium dichromate and metallurgical-grade chromic oxide at its plant in Eaglescliff and was the only western producer of chromic oxide for the production of chromium metal. London & Scandinavian Metallurgical Co. Ltd., a subsidiary of Metallurg Inc. (USA), produced chromium metal (Metal Bulletin, 1999a).

***Vietnam***.—Chromite mineral resources were reported to be moderate, with reserves of 24.5 million tons. Chromite was discovered in 1927 near Nui Nua Mountain in Thanh Hoa Province. Chromite deposits of economic value are widespread in the Quaternary basin of the northeastern foothills of Nui Nua Mountain. The basin extends over 36,000 square kilometers. The deposit is alluvial, ore grade is in the range of 1% to 5% $Cr_2O_3$, and the ratio of $Cr_2O_3$ to FeO is 2.2 to 2.4. The chromite has a small grain size. Proven reserves were 20.8 million tons of $Cr_2O_3$. Mining started in 1930, and production peaked in 1943 with 6,569 tons of concentrate. A second mining company was formed in 1956 to exploit the deposit. This company reached annual concentrate production of 31,552 to 36,084 tons between 1962 and 1963. Between 1990 and 1994, mine production ranged from 4,600 to 6,900 tons (Le, 1996, 1998; Metal Mining Agency of Japan, 1996; Chadwick, 1998).

***Zimbabwe.—***In 1997, Zimbabwe Alloys Ltd. reported production of 178,391 tons of chromite ore, 41,045 tons of ferrochromium-silicon, and 34,356 tons of low-carbon ferrochromium. Compared with 1996 statistics, production decreased from 188,586 tons for chromite ore and 33,000 tons for ferrochromium-silicon and increased from 30,421 tons for low-carbon ferrochromium.

Because production cost increased owing to lower ore quality and higher electrical energy cost, Zimbabwe Alloys closed its Inyala open pit mine and suspended operation of its Great Dyke II Mine at the end of 1997.

A new ferrochromium plant and a new stainless steel plant were being planned. Maranatha Holdings (Pvt.) planned Maranatha Ferrochrome (Pvt.) Ltd., a 25,000-ton-per-year high-carbon ferrochromium plant at Eiffel Flats. It purchased 7- and 10-megavolt-ampere furnaces and ancillary equipment from a dormant plant in Italy. Amble Mines (Pvt.) Ltd. was set up to mine reserves in the Middle Dyke (Ngezi) area. Project cost was estimated to be $8 million with $2 million reported spent. The smelter was expected to employ about 140 people. Zimbabwe Alloys and Zimasco Private Ltd. studied the possibility of merging to reduce cost (Ryan's Notes, 1998e, 1999a, b; TEX Report, 1998k; Business Day, 1999; Mining Mirror, 1999).

## Current Research and Technology

***Mineral Processing and Industrial Applications.—***Industry conducts research to develop new, more-efficient processes and to improve the efficiency of currently used processes. The Council for Mineral Technology (Mintek) of the Republic of South Africa conducts Government-sponsored, commercially sponsored, and cosponsored research and development on chromite ore and ferrochromium.

***Chromite Ore.—***At the Kemi chromite ore deposit in Finland, microstructure image analysis was used to estimate the concentration characteristics (Leinonen, 1998). The Kemi deposit was implaced 2.44 billion years ago and was metamorphosed 1.9 billion years ago. The metamorphosis resulted in the lowering of the ore grade, the reduction of host rock competency on one side of the deposit (talc, carbonate, and chlorite), and the creation of two minerals unique to the deposit—one pink (a chromium-chlorite mineral) and the other green (chromium-containing garnet). In addition, the ore dipped 70 degrees to the northwest, and the deposit was faulted. Underground mining was to be phased in over the next 10 years while open pit mining is phased out. Diamond drilling has been done along the deposit to collect deposit gravimetic information for planning purposes. Typical chromite ore density is 3.45 grams per metric cubic centimeter; densities of the best grades, however, are from 3.5 to 3.6 grams per metric cubic centimeter.

The Kemi Mine produced 1.1 million to 1.2 million tons per year of chromite ore with an average grade of 26% to 27% $Cr_2O_3$ from a 4.5-kilometer-long economic zone in which the deposit thickness varies from 30 centimeters to 40 meters. That average comprises ore graded between 20% (the cut-off grade) and 52% $Cr_2O_3$. A major challenge will be to mine so that the ratio of lump to concentrate meets the processing plant requirements. Leinonen (1998) found microstructure image analysis to be a useful tool for classifying chromite ore types at the Kemi deposit.

***Ferrochromium Production***.—Armitage (1999) reported that briquetting with lime-molasses followed by implementation of pelletizing with bentonite was first used in 1977 as part of the prereduction process at Lydenburg, South Africa. Pelletizing with sodium silicate was implemented in 1990 at Chromecorp's Rustenburg plant. In 1998, Samancor implemented a pelletizing and preheating process developed by Outokumpu. Hernic planned to implement the same process in 1999.

In comparing the economics of ferrochromium production based on South African ore from the LG-6 and UG-2 seams, Sciarone (1998) found that the lower cost of UG-2 ore relative to LG-6 ore was more than offset by the agglomeration cost of UG-2 ore. He also found that ferrochromium produced from UG-2 ore was worth about 8% less per ton, gross weight, than that produced from LG-6 ore because of the difference in the chromium-to-iron ratios of the ores.

Qiu and Zhong (1998) reported pelletizing Indian chromite ore concentrates and South African chromite ore fines. They reported that bentonite binder worked well for the Indian ore; the South African ore, however, required the addition of organic binder. Coke breeze was used as the fuel source for hardening the pellets. Temperature control was found to be critical.

On the basis of a modified structural grain model applied to the reaction of Outokumpu chromite ore with CO, Xiao and Holappa (1998) concluded that ore reduction is controlled by chemical and physical factors as diffusion through the chromite grain and pellet pores, and gas phase mass transfer. They predicted that increasing pellet porosity would significantly increase reduction rate and that increasing pellet radius or chromite ore grain size would decrease the reduction rate. Kekkonen, Marko, and Syynimaa (1998) reported that the amount of reduction for pellets increased with temperature from 1,420° C through 1,595° C while that of lumpy ore increased from 1,420° C through 1,520° C because the latter partially melted at that temperature. They based their conclusion on thermogravimetric analysis, optical and scanning electron microscopy, and microanalysis. They also found that the degree of reduction increased as the distance from the center of the ore or pellet increased and that interior reduction of pellets exceeded that of lump ore because CO gas more easily penetrates the pellets. On the basis of their study of Brazilian, Kazakhstani, South African, and Turkish ore samples reduced in a carbon tube furnace, Ringdalen and Olsen (1998) reported that the reduction rate is affected by mineralogical ore properties, including chromite mineral composition and type of gangue mineral. They found that preoxidation affected reduction rate; the effect, however, varied among ores.

Sun, Bo, and Zhau (1998) reported on the techniques they developed to reduce energy consumption in the production of low-carbon ferrochromium (carbon less than 0.06%) produced by the silicothermic method. These techniques were related to material, process, and operating factors.

Curr, Nelson, and McRas (1998) reported on the development of a low-carbon ferrochromium production process for South African chromite ore. The process uses a DC electric-arc furnace to make a high-chromium-to-iron-ratio slag that becomes the feed material for low-carbon ferrochromium production in a submerged-arc furnace. They estimated that a 10- to 12-megawatt furnace could produce about 20,000 tons per year of low-carbon ferrochromium graded at 65% chromium.

Chen (1998) reported on the effect of the ratio of magnesia to alumina measured in slag on the carbon content of high-carbon ferrochromium and the chromium content of slag. He found that carbon content of ferrochromium increases as the magnesia-to-alumina ratio in slag increases. The $Cr_2O_3$ content of slag decreased as the magnesia-to-alumina ratio was increased to 2.2 at which point $Cr_2O_3$ increased as the magnesia-to-alumina ratio increased.

Kato, Kawauchi, and Toyoda (1998) reported a three-step production process that they developed to produce ferrochromium for the superalloy industry. The process involved nitridation, acid treatment, and degassing to produce a low-carbon (0.01% carbon), high-chromium (90.3% chromium) ferrochromium.

Zhang (1998) developed an empirical equation for the solubility of carbon in ferrochromium melts. The model indicated that carbon solubility increases with temperature and with chromium content.

Kossyrev, Pavlov, and Olsen (1998) made an approximate determination of the phase relations and liquidus isotherms at 1,600° C and 1,700° C for the system $SiO_2$-CrO-MgO-$Al_2O_3$, where the weight ratio of $MgO/Al_2O_3=2.0$. The oxygen potential of the slag system was measured at 1,600° C.

Huo, Sun, and Chen (1998) described the hardware, software, and control strategy of a computer-based distributed control system (controller) for the production of low-carbon ferrochromium. They found that the controller improved electrode arc starting and furnace charging, eliminated arc blowout, and reduced electrical breaker trips and electrode breakage.

Booysen and others (1998) reported on an operational guidance system for a Creuso-Loire-Uddelholm converter based on a phenomenological heat and kinetic mass transfer model. The system was found to predict product carbon content accurately and was considered to be a candidate for online use and, ultimately, system control.

Cortie and others (1998) reported their successful production of lump ferrochromium directly from a melt by using a new process that avoids the disadvantages of slab casting, pig casting, and granulation. They identified a size range of 5 to 80 millimeters and a flattened ellipsoidal shape as ideal and were able to produce large blobs of charge chrome and low-carbon ferrochrome.

***Ferrochromium Slag Processing.—***Das and others (1998) tested low- to medium-intensity magnetic separation on Indian charge chrome slag to recover charge chrome contained in that slag. Having found the optimum magnetic field and particle size at bench scale, the authors tested recovery at a material feed rate 120 kilograms per hour and developed a conceptual flow sheet. Mashanyare and Guest (1997) reported on the ferrochromium-from-slag recovery process at Zimasco, which had 4.5 million tons of slag for which it constructed a metal-from-slag recovery plant to treat 170 tons per hour of slag. After the slag is crushed, the iron is magnetically removed. The material is then separated in an air-pulsed jig. In the size range processed, they recovered 96.7% of chromium contained in the slag, yielding a product containing more than 63% chromium and about 2% slag. Platias and Mirtec (1996) found that the production of ferrochromium in Greece resulted in a loss of 6% of chromium contained in the chromite ore feed that reports to slag. Of the chromium in slag, 30% to 35% was found to have been in metallic form with the remainder in oxide form. They recovered 95% of it by using dense media separation on slag in the size range of 30 to 3 millimeters. Serdar, Guven, and Hurman (1998) demonstrated that chromium (along with iron) is recoverable from ferrochromium slags by pyrometallurgical process. They reported that increased basicity of slag increased the percentage of chromite dissolved and reduced.

Olivier, Guest, and Parker (1998) extended the domain (reported in dump size versus head grade) for the economic recovery of metal from slag. By improving the efficiency of their gravimetric separation recovery process and by reducing capital cost for equipment through toll processing, applicability of the technology was improved.

***Stainless Steel.—***Nishikoori, Nishikawa, and Sorimachi (1994) reported on a steelmaking process that uses chromite pellets instead of ferrochromium as a source of chromium. The chromite ore pellets were 65% to 70% prereduced in a rotary kiln. Coke and chromite pellets were mixed in a smelting reduction process that permits high productivity and flexible raw material selection. The process was used to produce 20%

chromium-5% aluminum stainless steel for automobile catalytic converters.

***Environmental.—***Environmental concerns about chromium have resulted in a wide variety of studies to determine the chemical characteristics, natural background levels, sources of environmental emissions, movement of chromium in the environment, interaction of chromium with plants and animals, effect of chromium on plants and animals, measurement methods, and recovery technology.

Kettwig (1997) reported that Osmonics Company pilot tested a system that removed 99.9% of hexavalent chromium from contaminated water as part of a plating facilities remediation process.

E.I. du Pont de Nemours and Company and Lacerta Group were jointly developing a process to recover chromium from polyester base film (Chemical Marketing Reporter, 1997a). This film includes audio and video tape and computer cartridges and diskettes.

Castner and Null (1998) reported that hexavalent chromium compounds result from welding or cutting materials that contain chromium, such as nickel alloys, stainless steel, and some low-alloy steels. Anticipated OSHA reduction of chromium permissible exposure limits could impact the shipbuilding industry.

## Outlook

Edwards (1998) reviewed the causes of ferrochromium production development from 1960 through 1997. He found that the major reason for ferrochromium production growth was stainless steel production growth and reported technological developments that contributed to ferrochromium cost decline. From 1974 through 1994, world stainless steel production grew at an annually compounded rate of 4.1%. From 1970 through 1996, the price of ferrochromium dropped by 57%. A comparison of ex-works production cost showed South African producers to be the most cost-effective ferrochromium producers. On the basis of continued growth of stainless steel production, Edwards expected ferrochromium production growth to be 200,000 to 300,000 tons per year. Bennett (1998) reported that the outlook for ferrochromium production and price growth appeared to be good in the coming years. He reported that demand for ferrochromium was driven by stainless steel production, which has a long-term growth rate of 4.5%, which was forecast to continue. Price increases were expected to be mitigated by overcapacity in the ferrochromium production industry.

The outlook for chromium consumption in the United States and the rest of the world was about the same as that for stainless steel, which is the major end use for chromium worldwide. Thus, stainless steel industry performance largely determines chromium industry demand worldwide. (See the following section on stainless steel.)

The trend to supply chromium in the form of ferrochromium by chromite mining countries was expected to continue. With new, efficient ferrochromium production facilities and excess capacity in chromite-producing countries, production and capacity are expected to diminish in countries that produce ferrochromium but not chromite ore and in countries with small, less efficient producers, except where domestic industries are protected by quotas and tariffs. Further vertical integration of the chromium industry was expected as chromite-producing countries expand ferrochromium or stainless steel production capacity.

The Asian financial crisis caused demand for stainless steel in Asia to decline. That reduction in demand resulted in Asian-produced stainless steel competing for market share in Europe and North America. That competition for market share resulted in declining prices with subsequent influence on reducing the price and demand for ferrochromium as world markets adjusted. The effect of the Asian financial crisis was mitigated by reduced production from Kazakhstan where ownership issues interfered with production.

Schroeder (1999) made some disturbing observations based on examination of the chromium industry observations from 1972 to 1997. He showed that while stainless steel production grew by 3.9%, the price of stainless steel dropped by 3.6%. The price for ferrochromium also dropped by 3.6% during the same time period while the cost of production curve flattened out as a result of capacity additions at the low cost of production end of the curve that were implemented shortly after prices rose. Mross (1998) reported that on the basis of a 1967 index value, the price of stainless steel declined by 63% while the price of competitive materials (plastic, aluminum, and carbon steel) increased by 40% to 60%. Consequently, stainless steel has become inexpensive. Mross also reported that as a percentage of production cost, the raw material cost of stainless steel increased from 52% in 1995 to 60% in 1997. The declining cost of stainless steel coupled with rising relative raw material cost results in pressure to lower the price of ferrochromium. Schroeder (1999) reported that the net effect of these changes has been to reduce profit per unit of investment in the ferrochromium production industry; that is, since the mid-1980's, the ferrochromium industry made capacity expansion investments sufficient to double production; industry profit in the late 1990's, however, is the same as that generated in the early 1980's. To avoid the spiral of decreasing prices brought on by increasing low-cost production capacity that result in lower-than-expected profits, Schroeder proposed to increase the production capacity of current facilities through de-bottlenecking and improved efficiency. Schroeder also observed that restructuring in the ferrochromium and stainless steel producing parts of the chromium industry has been active. Some restructuring has resulted in companies abandoning the chromium industry or closing. These changes suggest that the price of ferrochromium and stainless steel may be set at levels inadequate to sustain business.

This appears to be a situation in which the marginal change in price has resulted in a similar change in consumption; that is, a 3.5% price decrease associated with a 3.9% production increase. Lower price is presumably a benefit to society as long as that price decrease does not cause efficient producers to go out of business. Although some stainless steel and some ferrochromium producers went out of business, and some companies sold their ferrochromium production facilities during the period of analysis; stainless steel and ferrochromium production has increased, so declining prices do not appear to have slowed production. Declining prices may well be the a cause of increased production. Declining profit per unit of investment appears to have mitigated investing in ferrochromium production facilities. Should production capacity expansion not keep pace with demand, price increases are likely to result. If production is price sensitive, withheld investment may well result in slowed production growth or worse. In addition, increased unit profits owing to withheld investment would then result in reduced total profits (compared to what they would have been assuming no change in production).

***Chromite Ore***.—Chromite ore production capacity is in balance with average consumption. Consumption capacity by ferrochromium plants, however, exceeds production capacity, which leads to short supply when demand surges, preventing ferrochromium producers from meeting surge demand. To improve chromite ore availability and to stabilize feed material price, ferrochromium producers invest in chromite-ore-producing mines. South African chromite ore production exceeded that of each of the second largest producers (India and Kazakhstan) in 1998 by greater than a factor of three. Redistribution of chromite ore reserves in India by the courts may result development of those resources, thereby increasing the position of India as a world supplier of chromite ore. Resolution of the ownership dispute in Kazakhstan and selection of a development plan in Albania may have the same effect in these countries.

O'Driscoll (1998) reviewed the nonmetallurgical-grade chromite ore market. The nonmetallurgical chromite ore markets are the chemical, refractory, and foundry markets. Nonmetallurgical chromite ore demand has been declining while metallurgical demand has been increasing. Based on O'Driscoll's survey of South African chromite ore producers and South African Minerals Bureau Statistics, nonmetallurgical chromite ore demand accounted for about 1 million tons out of 5.7 million tons, or about 20% of South African production. O'Driscoll estimated the world nonmetallurgical chromite ore demand to be 1.5 million tons, or 12% of world production and estimated world demand to break down among end-use industries as follows: chemical, 56.7%; refractory, 26.7%; and foundry, 16.7%. O'Driscoll reported that world refractory industry chromite ore demand has been declining while that of the chemical industry has been growing slightly and that of the foundry industry has been stable. He attributed the decline in refractory demand to two factors—primarily, environmental concerns, and, secondarily, the steel industry trend to using longer lasting refractory materials. Some applications result in the formation of environmentally threatening compounds on chromite refractories thereby causing a waste disposal problem. Reduced chromite refractory demand is demonstrated by the decline in general of refractory consumption in the Far East of 15 to 20 kilograms of refractory per ton of steel produced from 1970 through 1980 to 10 to 12 kilograms in 1998 and the decline in chrome-magnesite refractory brick production in the United States to 36,500 tons in 1995 from 104,500 tons in 1988. O'Driscoll (1999) reported that demand growth for chromite ore appeared good for metallurgical use; however, chemical growth was 1% to 2% in 1998 while refractory and foundry sand demand declined.

***Ferrochromium***.—Ferrochromium production is electrical energy intensive. Charge-grade ferrochromium requires 2,900 to 4,100 kilowatt-hours per ton of product, with efficiency varying with ore grade, operating conditions, and production process. Thus, ferrochromium plant location reflects a cost balance between raw materials and electrical energy supply. South African ferrochromium production exceeded that of the second largest producer in 1998 by greater than a factor or four. The South African share of ferrochromium production moved to about 40% in 1998 from 30% in 1994. A situation similar to that between chromite ore and ferrochromium producers exists between ferrochromium and stainless steel producers. Stainless steel producers have been investing in ferrochromium production plants.

***Stainless Steel***.—U.S. stainless steel production showed an average annual compound growth of 2.0% from 1994 through 1998. From 1950 through 1998, U.S. average annual compound growth was 2.8%. World stainless steel production showed growth during the same periods of 4.8% and 5.9%, respectively. Stainless steel production growth in the United States was about one-half that of world growth.

Stainless steel demand is price sensitive, and an important part of stainless steel cost is nickel cost (about 70% of stainless steel production requires nickel). Nickel availability and cost have been viewed as potential limitations to increased stainless steel production. The discovery and development of new nickel deposits projected to produce at near one-half the cost of current producers mitigates this potential limitation to stainless steel production growth.

Anticipating the effect of stainless steel market growth on chromium demand is complicated by stainless steel scrap use. Stainless steel scrap use displaces demand for ferrochromium and the chromite ore needed to make ferrochromium. Ferrochromium was estimated to supply 60% to 65% of chromium units in stainless steel, with scrap supplying the remaining 30% to 35% (Probert, 1997). The origin of that scrap was reported to have been 50% reclaimed, 35% revert, and 15% industrial (Ward, 1997).

***Chromium Chemicals***.—Chromium chemical production is geographically concentrated in developed economy countries. In 1998, major producing countries where large plants (capacity in excess of 100,000 tons of sodium dichromate per year) operate included Kazakhstan, Russia, the United Kingdom, and the United States. Moderate-sized production facilities were located in China, Japan, Romania, South Africa, and Turkey. Small-scale local producers operated in China and India.

Sodium dichromate demand in the United States was reported to be 155,000 tons in 1997 and 150,000 tons in 1996 while domestic production capacity was reported to be 156,000 tons in 1997. Distribution of this demand was 66% for chromic acid; 13%, leather tanning; 9%, chromic oxide; 6%, pigments; and 6%, miscellaneous (including wood preservation and metal finishing) (Chemical Marketing Reporter, 1997b).

***Chromium Metal***.—Major chromium metal producers include Russia and the United States (electrolytic producers) and France, Russia, and the United Kingdom (aluminothermic producers). Kazakhstan, a major chromite ore and ferrochromium producer, started chromium metal production.

## References Cited


Anderson, R.A, 1997a, Chromium as an essential nutrient for humans: Regulatory Toxicology and Pharmacology, v. 26, p. S35-S41.

———1997b, Lack of toxicity of chromium chloride and chromium picolinate in rats: Journal of the American College of Nutrition, v. 16, no. 3, p. 273-279.

———1998a, Chromium, glucose intolerance and diabetes: Journal of the American College of Nutrition, v. 17, no. 6, p. 548-555.

———1998b, Effects of chromium on body composition and weight loss: Nutrition Reviews, v. 56, no. 9, p. 266-270.

———1998c, Recent advances in the clinical and biochemical manifestations of chromium deficiency in human and animal nutrition: Journal of Trace Elements in Experimental Medicine, v. 11, p. 241-250.

Armitage, K.W., 1999, Ore pelletizing for ferrochrome production: MB Bulletin, Department of Minerals and Energy, Minerals Bureau, p. 3-4.

Bennett, Amy, 1998, The outlook for ferro-manganese, silico-manganese, and ferro-chrome, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 23-28.

Booysen, L.M., Nelson, L.R., Swamy, K.N., and Visser, Marius, 1998, Development of an operator guidance system for intermediate carbon charge chromium production, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 343-349.

Business Day, 1998, Hernic ferrochrome expands: Business Day, April 20, p. 13.

———1999, Zimbabwe merger to create chrome leader: Business Day, February 25, p. 1.

Calms, Luise, 1998, Largest ferrochrome plant opens in Witbank: Mining Weekly, August 14-20, p. 3.

Castner, H.R., and Null, C.L., 1998, Chromium, nickel, and manganese in shipyard welding fumes: Welding Research Supplement, June, p. 223-s-231-s.

Cesar, José Rafael de Andrade, 1998, Cromo: Sumário Mineral 1998, v.18, Departmento Nacional de Produção, Brasília, p. 40-41.

Chadwick, John, 1998, Vietnam visa: Mining Magazine, v. 178, no. 1, January, p. 2.

Chemical Marketing Reporter, 1997a, Title: Chemical Marketing Reporter, v. 251, no. 20, May 19, p. 7.

———1997b, Chemical profile—Sodium bichromate: Chemical Marketing Reporter, v. 252, no. 18, November 3, p. 53.

Chemical Weekly, 1998, US EPA offers technology to recover chrome from tannery effluents: Chemical Weekly, v. 43, no. 38, May 19, p. 75.

Chen, Yonggao, 1998, Studies on factors affecting carbon content in ferrochrome and chromium content in slag, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 189-194.

Cortie, M.B., Barker, I.J., Knight, D., and Levey, F., 1998, Improved methods for the lump casting of ferroalloys, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 394-400.

Curr, T.R., Nelson, L.R., and McRas, L.B., 1998, The selective carbothermic reduction of chromite, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 158-170.

Dai, Wei, 1999, The outlook of the ferroalloys industry and market in China: World Ferroalloys Conference, 2nd, Barcelona, March 14-16, 1999.

Das, B., Mohanty, J.K., Reddy, P.S.R., and Ansari, M.I., 1997, Characterization and beneficiation studies of charge chrome slag: Scandinavian Journal of Metallurgy, v. 26, no. 4, August 1, p. 153-157.

Edwards, A.M., 1998, Developments in technology for ferrochromium production, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 1-4.

Elkem ASA, 1999, Elkem annual report 1998: Elkem ASA, 69 p.

Engineering News, 1998, Chrome tanning-salts plant expansion opens: Engineering News, July 31-August 6, p. 20.

European Chemical News, 1998, Bayer looks for new partner in South African chrome project: European Chemical News, March 23-29, p. 5.

Fumagalli, Mario, 1998, Growth to continued in Italian stainless: Metal Bulletin Monthly, no. 329, May, p. 36-37, 39, 41.

Galkin, Alexander, 1999, Sopcheozersk Chromium Deposit—Mineral/technical assessement and prospects for development: International Chromium Development Association, spring meeting 1999, St. Petesburg, Russia, Conference Papers, variously paginated.

Gericke, W.A., 1998, Environmental solutions to waste products from ferrochrome production: , *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 51-58.

Huo, Naili, Sun, Gouhui, and Chen, Xiaojun, 1998, An advanced DCS control system for low-carbon ferrochromium production line, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 201-205.

Industrial Minerals, 1998a, Chromite production update: Industrial Minerals, no. 368, May, p. 12-13.

———1998b, New chromic acid plant for Kromsan: Industrial Minerals, no. 376, December, p. 14-15.

———1998c, Outokumpu ceases foundry chromite output: Industrial Minerals, no. 366, March, p. 12.

———1999a, Assmang new mine development: Industrial Minerals, no. 377, February, p. 31.

———1999b, Chrome International plant in commissioning: Industrial Minerals, no. 377, February, p. 31.

———1999c, Chromite news capsule: Industrial Minerals, no. 377, February, p. 31.

———1999d, Chromite production update: Industrial Minerals, no. 376, January, p. 76.

———1999e, Chromite supply sector in ownership unceraintty: Industrial Minerals, no. 376, January, p. 75.

Kato, Masanori, Kawauchi, Sotoaki, and Toyoda, Takeharu, 1998, Development of high quality ferrochromium alloy (NKK super-chrome), *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 189-194.

Kekkonen, Marko, Syynimaa, Holappa, Lauri, and Niemela, Pekka, 1998, Kinetic study on solid state reduction of chromite pellets and lumpy ores, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 141-146.

Kettwig, Kay, 1997, Osmosis removes chromium: Mining Environmental Management, September, p. 26.

Kossyrev, K.L., Pavlov, A.V., and Olsen, S.E., 1998, Phase equilibria and oxygen potential in SiO2-CrO-MgO-Al2O3 slags (MgO/Al2O3=2.0), *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 201-205.

Le, De Van, 1996, A summary of mineral resources and some ideas on mineral development of Vietnam in projects and resources: Metal Mining Agency of Japan, v. 1, no. 1, March, p. 3.

———1998, Status of mineral exploration and mining activities in Vietnam: DMR-CCOP-MMAJ Joint Seminar on Application of satellite image analysis in mineral exploration, February 17-19, 1998, p. 48.

Leinonen, Ossi, 1998, Use of chromite microstructure image analysis to estimate concentration characteristics in Kemi chrome ore: Oulu, Finland, Oulu University Press, 115 p.

Mashanyare, H.P., and Guest, R.N., 1997, The recovery of ferrochrome from slag at Zimasco: Mining Engineering, v. 10, no. 11, p. 1253-1258.

Metal Bulletin, 1997, Agreement signed for Albchrome revamp: Metal Bulletin, no. 8239, December 22, p. 5.

———1998a, Aksu production continues to plan: Metal Bulletin, no. 8316, October 8, p. 9.

———1998b, Albchrome finance approval within 15-20 days: Metal Bulletin, no. 8257, March 2, p. 11.

———1998c, Alumino-thermic Cr under pressure: Metal Bulletin, no. 8306, September 3, p. 10.

———1998d, China's stainless ambitions: Metal Bulletin, no. 8301, August 13, p. 13.

———1998e, Commissioning begins at Iran Alloy Steel: Metal Bulletin, no. 8309, September 15, p. 24.

———1998f, Dilokong project on schedule for May 1999 commissioning: Metal Bulletin, no. 8322, October 29, p. 8.

———1998g, Dilokong smelter project to proceed: Metal Bulletin, no. 8296, July 20, p. 7.

———1998h, Dwarsrivier deposit to see fast track development: Metal Bulletin, no. 8311, September 21, p. 9.

———1998i, Facor challenges government's decision on Sukinda mining agent: Metal Bulletin, no. 8294, July 13, p. 9.

———1998j, Gossan leases Selkirk smelter: Metal Bulletin, no. 8338, December 24, p. 9.

———1998k, Gossan plans to produce master alloys in Manitoba: Metal Bulletin, no. 8270, April 20, p. 12.

———1998l, Hernic expansion will not disrupt market: Metal Bulletin, no. 8271, April 23, p. 5.

———1998m, In brief: Metal Bulletin, no. 8300, August 10, p. 10.
———1998n, Indian producers call for lower power rates: Metal Bulletin, no. 8333, December 7, p. 9.
———1998o, Kazakh plant look to the future: Metal Bulletin, no. 8294, July, p. 9.
———1998p, Procoloro plans new mine and smelter: Metal Bulletin, no. 8288, June 22, p. 9.
———1998q, Turkish chromite producers suffer: Metal Bulletin, no. 8338, December 24, p. 8.
———1998r, UK consortium outlines rosle in Albchrome revamp: Metal Bulletin, no. 8242, January 8, p. 9.
———1999a, Elementis profits fall in tough chromium market: Metal Bulletin, no. 8357, March 8, p. 7.
———1999b, Ferom ceases production, court decides future: Metal Bulletin, no. 8345, January, p. 7.
———1999c, In brief: Metal Bulletin, no. 8356, March 4, p. 8.
———1999d, Jugochrom is unaffected by Balkan war: Metal Bulletin, no. 8365, Month, p. 7.
———1999e, FeCr production overhang remains: Metal Bulletin, no. 8352, February 18, p. 13.
Metal Mining Agency of Japan, 1996, Production of principal mineral and metals in Vietnam: Overseas Mining Information Bulletin-Japan, v. 26, no. 4, November, p. 48.
Mining Journal, 1998a, Assmang plans new mine: Mining Journal, v. 331, no. 8496, September 4, p. 178.
———1998b, Outokumpu's integrated strategy: Mining Journal, v. 330, no. 8484, May 15, p. 389-390.
———1998c, Tibet mineral potential: Mining Journal, v. 330, no. 8476, April 17, p. 301.
Mining Mirror, 1999, Zimbabwe welcomes now ferrochrome smelting project: Mining Mirror, February, p. 51.
Mining Weekly, 1998a, Chrome ore producer mulls over new megamine plan: Mining Weekly, v. 4, no. 1, January 16-22, p. 1, 14, 16-22.
———1998b, R137 million ferrochrome contact awarded: Mining Weekly, v. 4, no. 17, July 17-23, p. 8.
———1998c, R200m third furnace for Brits chrom firm: Mining Weekly, v. 4, no. 15, April 24-30, p. 13.
Mross, Juergon, 1998, When two markets collide: Ryan's Notes 1998 Ferroalloy Conference, Boca Raton, FL, October 25-27, 1998, handout, unpaginated.
Nishikoori, Masanori, Nishikawa, Hiroshi, and Sorimachi, Ken-ichi, 1994, Recent progress of stainless steelmaking process at Kawaski Steel: Kawasaki Steel Technical Report, no. 31, November 1994, p. 5-11.
O'Driscoll, Mike, 1998, Chromite supply a question of ownership: Industrial Minerals, no. 366, March, p. 51, 53, 55-57, 59, 61-63, 65-67.
———1999, Chromite in crisis producers hold out for October recovery: Industrial Minerals, No. 377, February 1999, p. 25, 29, 31-33.
Olivier, B.J., Guest, R.N., and Parker, J.A.L., 1998, The production of ferroalloys by the toll treatment of slag dumps, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 180-183.
Outokumpu Oy, Outokumpu annual report 1998, 1999: Outokumpu Oy, April, 80 p.
Papp, J.F., 1999, Chromium Ch. *in* Mineral Commodity Summaries 1999, U.S. Geological Survey, p. 48-49.
Pirie, P.S., 1998, Russia—Stainless shines against a dark backdrop: Metal Bulletin Monthly, no. 329, May, p. 43, 45, 47.
Platias, S.A., and Mirtec, S.A., 1996, Recycling of waste materials in a ferrochrome industry: International Symposium on Extraction and Processing for the Treatment and Minimization of Wastes, 2d, Phoenix, AZ, October 27-30, 1996, Proceedings, p. 741-748.
Platt's Metals Week, 1997, JMC, Mitsui in JV with Samancor: Platt's Metals Week, v. 68, no. 34, August 25, p. 10.
———1998a, Chrome softens in US, Transvaal, sought in Quebec: Platt's Metals Week, v. 69, no. 24, June 15, p. 13.
———1998b, Ferrochrome supplies reported growing in Europe, US: Platt's Metals Week, v. 69, no. 16, April 20, p. 6- 7.
———1999, Japan to cut ferroalloy import duties: Platt's Metals Week, v. 70, no. 1, January 4, p. 4.
Probert, P.J., 1997, Global ferrochrome into the millennium: Ryan's Notes 1997 Ferroalloys Conference, Boca Raton, FL, November 4, 1997, handout, unpaginated.
Qiu, Fangming, and Zhong, Lin, 1998, A preliminary study on pellet-sintering of chromite fines, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 184-188.
Resource Information Unit, 1998a, Chromium: Register of Australian Mining 1998/99, 655 p.
———1998b, Danelagh Resources Pty. Ltd.: Register of Australian Mining 1998/99, 655 p.
Ringdalen, Eli, and Olsen, S.E., 1998, the effect of chromite ore mineralogy on reduction mechanism and reducibility, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 147-152.
Ruffini, Antonio, 1998, Samancor in large capex projects: African Mining v. 3, no. 5, September-October, p. 63 and 65.
Ryan's Notes, 1998a, Elkem's agents want relief: Ryan's Notes, v. 4, no. 28, July 13, p. 1.
———1998b, Kazakhstan ferroalloy industry stabilizing: Ryan's Notes, v. 4, no. 26, June 29, p. 2-3.
———1998c, KazChrome ownership still unresolved; new attempt to revive Albanian Cr: Ryan's Notes, v. 4, no. 1, January 5, p. 1.
———1998d, Uneasy quiet in ferrochrome market: Ryan's Notes, v. 4, no. 22, June 1, p. 2-3.
———1998e, FeCr buyers fighting higher prices; JCI and Sudelektra face April 1 deadlines: Ryan's Notes, v. 4, no. 13, March 30, p. 2.
———1999a, Charge chrome price rollover: Ryan's Notes, v. 5, no. 14, April 5, p. 1.
———1999b, Has ferrochrome finally bottomed?: Ryan's Notes, v. 5, no. 13, March 29, p. 2.
———1999c, Low FeCr prices force KazChrome to cut back; ore low C FeCr production: Ryan's Notes, v. 5, no. 12, March, p. 2.
———1999d, Producer resistance up as FeCr prices appear to hit bottom: Ryan's Notes, v. 5, no. 1, January 4, p. 1.
———1999e, Turkish FeCr contracts set: Ryan's Notes, v. 5, no. 7, February 15, p. 2-3.
Samancor Limited, 1998, Samancor Limited annual report 1998: Samancor Limited, 58 p.
Saretski, Alexander, 1999, Overview of Russian chrome metal industry: International Chromium Development Association, spring meeting 1999, St. Petesburg, Russia, Conference Papers, variously paginated.
Schroeder, W.H., 1999, Evolving structure of the ferroalloy industry: CRU's World Ferroalloys Conference, 2nd, Barcelona, Spain, March 14-16,1999, handout, unpaginated.
Sciarone, M., 1998, South African chrome ore for the production of charge chrome, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 153-157.
Serdar, K.C., Guven, Akdogan, and Hurman, E.R., 1998, Chromium recovery from ferro-chromium slags, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 180-183.
South African Mining, Gold, Coal, and Base Minerals, 1997, Samancor pelletizing project will reduce mining costs: South African Mining, Gold, Coal, and Base Minerals, July, p. 17 and 34.
Sun, Yihua, Bo, Hongyuan, and Zhau, Wenbiao, 1998, Technical methods for reducing power consumption in smelting extra-low carbon ferrochromium, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 206-211.
Terlovoy, Vladimir, 1999, Overview of the CIS stainless steel industry: International Chromium Development Association, spring meeting 1999, St. Petesburg, Russia, Conference Papers, variously paginated.
TEX Report, 1998a, Assomag/SAfrica has taken over chrome resources in Eastern Belt: TEX Report, v. 30, no. 7154, September 4, p. 8.
———1998b, Chrome resources and stainless steel situation in India: Tex Report, v. 30, no. 7038, March 18, p. 4.
———1998c, Emei ferroalloy works/China has been taken over by Sichuan Province: TEX Report, v. 30, no. 7181, October 15, p. 9.
———1998d, Ferro-alloy works in China have faced a big turning point: TEX Report, v. 30, no. 7090, June 3, p. 10-11.
———1998e, Glencore's outlook for ferro-chrome market: TEX Report, v. 30, no. 7215, December 4, p. 1-2.
———1998f, Hernic/S. Africa Embarks upon construction of no. 3 electric furnace for Fe-Cr: TEX Report, v. 30, no. 7060, April 17, p. 1.
———1998g, Import duties on ferro-alloys and nickel are reduced from January 1999: TEX Report, v. 30, no. 7230, December 28, p. 2.
———1998h, Iranian Cr-Ore 20,000 tons for NKK arrive end this month: TEX Report, v. 30, no. 7031, March 9, p. 2.
———1998i, Mitsubishi Corp. has acquired right to sell Fe-Cr from Hernic: TEX Report, v. 30, no. 7063, April 22, p. 1.
———1998j, No. 3 electric furnaceat Hernic to be commissioned in May-June next year: TEX Report, v. 30, no. 7126, July 24, p. 2.
———1998k, Production aspect of chrome at Zimbabwe Alloys in 1997: TEX Report, v. 30, no. 7176, October 8, p. 4.
———1998l, Representatives of Kraoma/Madagascar came to Japan last week:

TEX Report, v. 30, no. 7184, October 20, p. 2.
———1998m, Suedelektra is going to take over 100% of CMI: TEX Report, v. 30, no. 7118, July 13, p. 1.
———1998n, TISCO/India expands chrome operations: Tex Report, v. 30, no. 7207, November 24, p. 12.
———1999a, January imports of s/s scrap by discharging port in December 1998: TEX Report, v. 31, no. 7263, February 25, p. 10-11.
———1999b, (Custom statistics) December 1998 Japan's exports of ferro-alloys: TEX Report, v. 31, no. 7259, February 19, p. 6.
———1999c, (Customs statistics) December 1998 Japan's imports of rare metal: TEX Report, v. 31, no. 7257, February 17, p. 5.
———1999d, (Custom statistics) December 1998 Japan's imports of raw materials ores (for ferro-alloys production): The TEX Report, v. 31, no. 7257, February 17, p. 6.
———1999e, Japan's exports of stainless steel products in year 1998 decreased slightly: TEX Report, v. 31, no. 7261, February 23, p. 2.
———1999f, Japan's output of ferro-alloys in year 1998: TEX Report, v. 31, no. 7258, February 18, p. page 3-4.
———1999g, Orbit of Chinese ferro-alloys in 1998 referring to its customs-statistics (2): TEX Report, v. 31, no. 7284, March 29, p. 2-3.
———1999h, Orbit of Chinese ferro-alloys in 1998 referring to its customs-statistics (4): TEX Report, v. 31, no. 7286, March 31, p. 3.
———1999i, Output of stainless steel in December 1998 continued cutbacks: TEX Report, v. 31, no. 7257, February 17, p. 10.
———1999j, Production of ferro- alloys in December '98: TEX Report, v. 31, no. 7258, February 18, p. 4.
———1999k, Raw materials supply/demand in ROK in December '98: TEX Report, v. 31, no. 7270, March 8, p. 7.
———1999l, Taiwan's imports of HC-Fe-Cr in December 1998: TEX Report, v. 31, no. 7280, March 23, p. 2.
U.S. Department of Health and Human Services, 1998, Indirect food additives—Adjuvants, production aids, and sanitizers: Federal Register, v. 63, no. 214, November 5, p. 59709-59710.
U.S. Environmental Protection Agency, 1998a, Effluent limitations guidelines, pretreatment standards, and new source performance standards for the landfills point source category: Federal Register, v. 63, no. 25, February 6, p. 6426-6463.
———1998b, Land disposal restrictions phase IV—Final rule promulgating treatment standards for metal wastes and mineral processing wastes; mineral processing secondary materials and Bevill exclusion issues; treatment standards for hazardous soils, and exclusion of recycled wood preserving wastewaters: Federal Register, v. 63, no. 100, May 26, p. 28556-28604.
———1998c, National primary drinking water regulations—Consumer confidence reports: Federal Register, v. 63, no. 160, August 19, p. 44512-44536.
———1998d, National recommended water quality criteria: Federal Register, v. 63, no. 234, December 7, p. 67548-67558.
van der Walt, Zacharias, 1998, Recent and anticipated developments of ferroalloys in South Africa: , *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 43-47.
Vilppula, Ahti, 1999, JSC Kazchrome/Alloys SA (Belgium), Presentation on the outlook for chromium in Kazakhstan, June.
Ward, Josephine, 1997, The chromium bungee jump: Metal Bulletin's International Ferro-Alloys conference, 13th, Miami, November 16-18, 1997, handout, 15 p.
Xiao, Yanping, and Holappa, Lauri, 1998, Kinetic modeling on solid state reduction of chromite pellet with CO, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 135-140.
Zhang, Jian, 1998, Carbon solubility and mass action concentration of Fe-Cr-C melts, *in* Cai, Junwei and Others, eds: International Ferroalloys Congress, 8th, Beijing, June 7-10, 1998, Proceedings, p. 195-200.

## SOURCES OF INFORMATION

### U.S. Geological Survey Publications

Chromium. Ch. in Mineral Commodity Summaries, annual.[1]
Chromium. Ch. in Minerals Yearbook, annual.[1]
Chromium. Ch. in United States mineral resources, U.S. Geological Survey Professional Paper 820, 1973.
International Strategic Minerals Inventory summary report—Chromium, U.S. Geological Survey Circular 930-B, 1984.
Mineral Industry Surveys, monthly.[1]

### Other Sources

American Iron and Steel Institute.
American Metal Market.
Chromite. Ch. in Industrial Rocks and Minerals.
Chromium. Ch. in Mineral Facts and Problems U.S. Bureau of Mines Bulletin 675, 1985.
CRU Metal Monitor.
The Economics of Chromium (Roskill Information Services, London).
Ferro-Alloy Directory and Databook (Metal Bulletin, London).
Ferro Alloys Manual (The TEX Report, Tokyo).
Ferrous Mineral Commodities Produced in the Republic of South Africa (South African Department of Mineral and Energy Affairs Directory D8).
International Chromium Development Association (Paris).
South Africa's Minerals Industry (Minerals Bureau, South Africa).
Stainless Steel Databook (Metal Bulletin Books, London).
Strategic and Critical Materials Report to the Congress (Department of Defense).

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

TABLE 1
SALIENT CHROMIUM STATISTICS 1/

(Metric tons, contained chromium unless otherwise specified)

| | | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|
| World production: | | | | | | |
| Chromite ore (mine) 2/ | | 3,130,000 r/ | 4,250,000 r/ | 3,490,000 r/ | 4,020,000 r/ | 3,820,000 e/ |
| Ferrochromium (smelter) 3/ | | 2,030,000 r/ | 2,500,000 r/ | 2,170,000 r/ | 2,650,000 r/ | 2,710,000 e/ |
| Stainless steel 4/ | | 2,350,000 | 2,640,000 r/ | 2,640,000 r/ | 2,880,000 r/ | 2,840,000 e/ |
| U.S. supply: | | | | | | |
| Components of U.S. supply: | | | | | | |
| Domestic mines | | -- | -- | -- | -- | -- |
| Secondary | | 99,000 | 112,000 | 98,400 | 120,000 | 105,000 |
| Imports: | | | | | | |
| Chromite ore | | 59,600 | 81,400 | 79,200 | 96,600 | 118,000 |
| Chromium chemicals | | 9,210 | 8,360 | 7,060 | 6,430 | 9,070 |
| Chromium ferroalloys | | 198,000 | 319,000 | 267,000 | 237,000 | 245,000 |
| Chromium metal | | 6,520 | 7,040 | 8,730 | 9,800 | 9,510 |
| Stocks, January 1: | | | | | | |
| Government | | 1,210,000 | 1,170,000 | 1,120,000 | 1,070,000 | 1,020,000 |
| Industry | | 103,000 | 101,000 | 80,100 | 72,800 | 71,900 |
| Total U.S. supply | | 1,690,000 | 1,790,000 | 1,660,000 | 1,610,000 | 1,580,000 |
| Distribution of U.S. supply: | | | | | | |
| Exports: | | | | | | |
| Chromite ore | | 14,000 | 5,740 | 21,900 | 5,890 | 39,900 |
| Chromium chemicals | | 11,700 | 14,700 | 18,200 | 16,700 | 17,500 |
| Chromium ferroalloys and metal | | 7,600 | 6,260 | 10,800 | 7,710 | 5,000 |
| Stocks, December 31: | | | | | | |
| Government | | 1,170,000 | 1,120,000 | 1,060,000 | 1,020,000 | 928,000 |
| Industry | | 101,000 | 80,400 | 74,300 | 71,900 | 57,900 |
| Apparent consumption | | 390,000 | 566,000 | 480,000 | 487,000 r/ | 530,000 |
| Reported consumption | | | | | | |
| Chromite ore and concentrates (gross weight) | | 322,000 | 351,000 | 282,000 | 350,000 | 269,000 |
| Chromite ore average $Cr_2O_3$ (percentage) | | 47.3 | 43.8 | 45.2 | 45.1 | 45.4 |
| Chromium ferroalloys (gross weight) | | 346,000 | 334,000 | 328,000 | 383,000 | 429,000 |
| Chromium metal (gross weight) | | 3,960 | 4,600 | 4,620 | 4,990 | 4,730 |
| Stocks, December 31 (gross weight): | | | | | | |
| Government: | | | | | | |
| Chromite ore | | 1,470,000 | 1,320,000 | 1,170,000 | 1,090,000 | 885,000 |
| Chromium ferroalloys | | 1,080,000 | 1,070,000 | 1,040,000 | 1,020,000 | 974,000 |
| Chromium metal | | 7,690 | 7,690 | 7,720 | 7,720 | 7,720 |
| Industry, producer | | 8,070 | 8,430 | 6,450 | 10,900 | W |
| Industry, consumer: | | | | | | |
| Chromite ore | | 266,000 | 205,000 | 173,000 | 175,000 | 159,000 |
| Chromium ferroalloys | | 14,700 | 22,500 | 27,300 | 16,500 | 18,400 |
| Chromium metal | | 292 | 264 | 211 | 233 | 215 |
| Prices, average annual: | | | | | | |
| Chromite ore, per ton gross weight 5/ | | $55.00 | $60.00 | $75.00 | $73.00 | $68.00 |
| Ferrochromium, per pound chromium content 6/ | | $0.37 | $0.70 | $0.51 | $0.48 | $0.47 |
| Chromium metal, per pound gross weight 7/ | | $3.70 | $3.97 | $4.15 | $4.15 | $4.15 |
| Value of trade: 8/ | | | | | | |
| Exports | thousands | $69,900 | $83,200 | $111,000 | $107,000 | $102,000 |
| Imports | do. | $254,000 | $545,000 | $463,000 | $450,000 | $421,000 |
| Net trade 9/ | do. | ($185,000) | ($461,000) | ($352,000) | ($343,000) | ($319,000) |
| Stainless steel (gross weight): | | | | | | |
| Production 10/ | | 1,830,000 | 2,030,000 | 1,920,000 | 2,160,000 | 1,980,000 |
| Exports | | 107,000 | 180,000 | 162,000 | 199,000 | 206,000 |
| Imports | | 762,000 | 732,000 | 781,000 | 774,000 | 862,000 |
| Scrap: | | | | | | |
| Receipts | | 582,000 | 658,000 | 579,000 | 706,000 | 616,000 |
| Consumption | | 1,000,000 | 1,110,000 | 1,040,000 | 1,140,000 | 1,030,000 |
| Exports | | 299,000 | 368,000 | 303,000 | 370,000 | 298,000 |
| Imports | | 43,000 | 43,000 | 50,000 | 64,000 | 57,000 |
| Value of trade: | | | | | | |
| Exports | thousands | $357,000 | $615,000 | $583,000 | $653,000 | $622,000 |
| Imports | do. | $1,500,000 | $1,810,000 | $1,880,000 | $1,720,000 | $1,680,000 |
| Scrap exports | do. | $190,000 | $325,000 | $234,000 | $231,000 | $176,000 |
| Scrap imports | do. | $20,200 | $33,800 | $28,500 | $33,700 | $21,600 |
| Net trade 9/ 11/ | do. | ($1,640,000) | ($2,060,000) | ($2,200,000) | ($2,110,000) | ($2,100,000) |

See footnotes at end of table.

TABLE 1--Continued
SALIENT CHROMIUM STATISTICS 1/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to not more than three significant digits; may not add to totals shown.
2/ Calculated assuming chromite ore to average 44% $Cr_2O_3$ that is 68.42% chromium.
3/ Calculated assuming chromium content of ferrochromium to average 57%.
4/ Calculated assuming chromium content of stainless steel to average 17%.
5/ Time average price of South African chromite ore as reported in Platt's Metals Week.
6/ Time average price of imported high-carbon chromium containing 50% to 55% chromium, as reported in Platt's Metals Week.
7/ Time average price of electrolytic chromium metal as reported in Platt's Metals Week.
8/ Includes chromite ore, chromium ferroalloys, metal, and chemicals.
9/ Number in parenthesis indicates that imports are greater than exports.
10/ Data on stainless steel production from American Iron and Steel Institute, quarterly production of stainless and heat-resisting raw steel.
11/ Includes stainless steel and stainless steel scrap.

TABLE 2

PRINCIPAL U.S. PRODUCERS OF CHROMIUM PRODUCTS IN 1998, BY INDUSTRY

| Industry and company | Plant |
|---|---|
| Metallurgical: | |
| Elkem A/S, Elkem Metals Co. | Marietta, OH. |
| Macalloy Corp. | Charleston, SC. |
| Refractory: | |
| Harbison-Walker Refractories, a subsidiary of Global Industrial Technologies | Hammond, IN. |
| National Refractories & Minerals Corp. | Moss Landing, CA, and Columbiana, OH. |
| North American Refractories Co. Ltd. | Womelsdorf, PA. |
| Chemical: | |
| Elementis Chromium LP | Corpus Christi, TX. |
| Occidental Chemical Corp. | Castle Hayne, NC. |

TABLE 3

PRODUCTION, SHIPMENTS, AND STOCKS OF CHROMIUM FERROALLOYS AND METAL, AND OTHER CHROMIUM MATERIALS IN THE UNITED STATES 1/

(Metric tons)

| Year | Net production: Gross weight | Net production: Chromium content | Net shipments | Producer stocks, December 31 |
|---|---|---|---|---|
| 1997 | 60,700 | 40,900 | 56,300 | 10,900 |
| 1998 | W | W | W | W |

W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits.

TABLE 4
U.S. CONSUMPTION OF CHROMIUM FERROALLOYS AND METAL, BY END USE 1/

(Metric tons, gross weight unless noted)

| End use | Ferrochromium: Low-carbon 2/ | Ferrochromium: High-carbon 3/ | Ferro-chromium-silicon | Other | Total |
|---|---|---|---|---|---|
| 1997: | | | | | |
| Steel: | | | | | |
| Carbon | 4,120 | 9,580 | 146 | 369 | 14,200 |
| Stainless and heat-resisting | 8,630 r/ | 251,000 | 35,900 | 159 | 296,000 |
| Full-alloy | 4,380 | 26,800 | 1,580 | 46 | 32,800 |
| High-strength, low-alloy, electric | 2,290 | 2,310 | 7,490 | W | 12,100 |
| Tool | W | 3,840 | W | W | 3,840 |
| Cast irons | 724 | 3,620 | W | 332 r/ | 4,680 r/ |
| Superalloys | 2,340 | W | W | 4,370 | 6,720 |
| Welding materials 4/ | 176 | 167 | 6 | 179 | 528 |
| Other alloys 5/ | 478 | 434 | -- | 1,610 | 2,520 |
| Miscellaneous and unspecified | 1,450 | 5,680 | 7,710 | 44 | 14,900 |
| Total 6/ | 24,600 | 304,000 | 52,800 | 7,110 7/ | 388,000 |
| Chromium content | 16,700 | 195,000 | 18,800 r/ | 5,630 | 236,000 r/ |
| Stocks, December 31, 1997 | 1,760 | 13,800 | 698 | 448 8/ | 16,700 |
| 1998: | | | | | |
| Steel: | | | | | |
| Carbon | NA | NA | NA | NA | 12,900 |
| Stainless and heat-resisting | NA | NA | NA | NA | 309,000 |
| Full-alloy | NA | NA | NA | NA | 29,500 |
| High-strength, low-alloy, electric | NA | NA | NA | NA | 11,400 |
| Tool | NA | NA | NA | NA | 2,670 |
| Cast irons | NA | NA | NA | NA | 3,110 |
| Superalloys | NA | NA | NA | NA | 6,610 |
| Welding materials 4/ | NA | NA | NA | NA | 463 |
| Other alloys 5/ | NA | NA | NA | NA | 4,350 |
| Miscellaneous and unspecified | NA | NA | NA | NA | 54,100 |
| Total 6/ | NA | NA | NA | NA | 434,000 9/ |
| Chromium content | NA | NA | NA | NA | NA |
| Stocks, December 31, 1998 | NA | NA | NA | NA | 18,600 10/ |

r/ Revised. NA Not available. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
1/ Data are rounded to not more than three significant digits; may not add to totals shown.
2/ Contains less than 3% carbon.
3/ Contains 3% or more carbon.
4/ Includes structural and hard-facing welding material.
5/ Includes cutting materials and magnetic, aluminum, copper, nickel, and other alloys.
6/ Includes estimates.
7/ Includes 4,990 tons of chromium metal.
8/ Includes 233 tons of chromium metal.
9/ Includes 4,730 tons of chromium metal.
10/ Includes 215 tons of chromium metal.

TABLE 5
U.S. CONSUMER STOCKS OF CHROMITE ORE, CHROMIUM FERROALLOYS, AND METAL, DECEMBER 31 1/

(Metric tons, gross weight)

| Industry | 1997 | 1998 |
|---|---|---|
| Chromite ore: | | |
| Chemical and metallurgical | 167,000 | W |
| Refractory | 7,520 | W |
| Total | 175,000 | 159,000 |
| Chromium ferroalloy and metal: | | |
| Low-carbon ferrochromium | 1,760 | NA |
| High-carbon ferrochromium | 13,800 | NA |
| Ferrochromium-silicon | 698 | NA |
| Other 2/ | 448 | NA |
| Total | 16,700 | 18,600 |

NA Not available. W Withheld to avoid disclosing company proprietary data.
1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Includes chromium metals stocks of 233 tons in 1997 and 215 tons in 1998.

TABLE 6
U.S. GOVERNMENT STOCKPILE YEAREND INVENTORIES AND CHANGE FOR CHROMIUM 1/ 2/

(Metric tons, gross weight)

| | | | Change 3/ | |
|---|---|---|---|---|
| Material | 1997 | 1998 | Quantity | Percentage 4/ |
| Chromite ore: | | | | |
| Chemical | 217,000 | 211,000 | (6,450) | (3) |
| Metallurgical | 565,000 | 387,000 | (178,000) | (31) |
| Refractory | 309,000 | 287,000 | (21,900) | (7) |
| Chromium ferroalloys: | | | | |
| Ferrochromium-silicon | 52,700 | 51,200 | (1,520) | (3) |
| High-carbon ferrochromium | 689,000 | 645,000 | (44,000) | (6) |
| Low-carbon ferrochromium | 283,000 | 278,000 | (4,770) | (2) |
| Chromium metal: | | | | |
| Aluminothermic | 2,670 | 2,670 | -- | -- |
| Electrolytic | 5,050 | 5,050 | -- | -- |

1/ Includes specification- and nonspecification-grade materials.
2/ Data are rounded to not more than three significant digits.
3/ Number in parentheses indicates decrease.
4/ Quantity change as a percentage of stocks before sale.

Source: Defense Logistics Agency.

TABLE 7
TIME-VALUE RELATIONS FOR CHROMITE ORE, FERROCHROMIUM,
AND CHROMIUM METAL 1/ 2/

(Annual average value, dollars per metric ton)

| Material | 1997 | | 1998 | |
|---|---|---|---|---|
| | Contained chromium | Gross weight | Contained chromium | Gross weight |
| Chromite ore: | | | | |
| Not more than 40% chromic oxide | 777 | 160 | 402 | 110 |
| More than 40% but less than 46% chromic oxide | 239 | 75 | 462 | 142 |
| 46% or more chromic oxide | 223 | 72 | 222 | 73 |
| Average | 232 | 74 | 224 | 74 |
| Ferrochromium: | | | | |
| High-carbon 3/ | 1,020 | 562 | 901 | 500 |
| Medium-carbon 4/ | 1,010 | 542 | 716 | 448 |
| Low-carbon 5/ | 2,120 | 1,400 | 1,750 | 1,160 |
| Average | 1,210 | 687 | 1,030 | 584 |
| Chromium metal | XX | 7,420 | XX | 7,580 |

XX Not applicable.
1/ Based on customs value of chromium contained in imported material.
2/ Data are rounded to not more than three significant digits; may not add to totals shown.
3/ More than 4% carbon.
4/ Carbon more than 3%, but not more than 4%.
5/ Carbon not more than 3%.

TABLE 8
PRICE QUOTATIONS FOR CHROMIUM MATERIALS AT BEGINNING AND END OF 1998

| Material | January | December | Year average |
|---|---|---|---|
| Dollars per metric ton of product: | | | |
| Chromite ore: | | | |
| South Africa | 65-75 | 60-65 | 68 |
| Turkey | 140-150 | 140-150 | 145 |
| Cents per pound of chromium: | | | |
| High-carbon ferrochromium: | | | |
| Imported: | | | |
| 50% to 55% chromium | 48-50 | 35-38 | 47 |
| 60% to 65% chromium | 44.5-46 | 35-40 | 45 |
| Low-carbon ferrochromium: | | | |
| Imported: | | | |
| 0.05% carbon | 83-88 | 77-79 | 85 |
| 0.10% carbon | 75-78 | 61-63 | 73 |
| Cents per pound of product: | | | |
| Chromium metal (domestic): | | | |
| Electrolytic | 415.0 | 415.0 | 415.0 |
| Elchrome | 575.0 | 450.0 | 529.0 |

Source: Platt's Metals Week.

TABLE 9
U.S. EXPORTS OF CHROMIUM MATERIALS, BY TYPE 1/

| HTSUSA 2/ | Type | 1997 Quantity (kilograms) | 1997 Value (thousands) | 1998 Quantity (kilograms) | 1998 Value (thousands) | Principal destinations, 1998 |
|---|---|---|---|---|---|---|
| 2610.00.0000 | Chromite ore and concentrate, gross weight | 18,500,000 | $4,200 | 121,000,000 | $9,230 | Norway (52%); Sweden (36%); Canada (7%). |
| | Metal and alloys: | | | | | |
| 8112.20.0000 | Chromium metal, gross weight 3/ | 2,340,000 | 17,400 | 1,040,000 | 13,000 | Japan (56%); Canada (30%); Netherlands (3%). |
| | Chromium ferroalloys: | | | | | |
| 7202.41.0000 | High-carbon ferrochromium, gross weight 4/ | 7,220,000 | 6,980 | 4,840,000 | 4,210 | Mexico (54%); Canada (42%). |
| 7202.41.0000 | High-carbon ferrochromium, contained weight 4/ | 4,330,000 | -- | 2,980,000 | -- | |
| 7202.49.0000 | Low-carbon ferrochromium, gross weight 5/ | 1,740,000 | 3,010 | 1,380,000 | 2,100 | Canada (46%); Mexico (28%); Netherlands (9%); United Kingdom (6%); Venezuela (4%). |
| 7202.49.0000 | Low-carbon ferrochromium, contained weight 5/ | 963,000 | -- | 841,000 | -- | |
| 7202.50.0000 | Ferrochromium-silicon, gross weight | 214,000 | 238 | 387,000 | 402 | Canada (85%); Mexico (12%); United Kingdom (2%). |
| 7202.50.0000 | Ferrochromium-silicon, contained weight | 74,800 | -- | 135,000 | -- | |
| | Total ferroalloys, gross weight | 9,180,000 | 10,200 | 6,610,000 | 6,710 | |
| | Total ferroalloys, contained weight | 5,360,000 | -- | 3,960,000 | -- | |
| | Chemicals: (gross weight) | | | | | |
| | Chromium oxides: | | | | | |
| 2819.10.0000 | Chromium trioxide | 12,700,000 | 24,400 | 10,100,000 | 19,600 | Canada (36%); Brazil (21%); Australia (8%); Mexico (6%); Chile (4%); Korea, Republic of (4%); Taiwan (4%); New Zealand (4%); Japan (3%). |
| 2819.90.0000 | Other | 2,870,000 | 14,200 | 4,980,000 | 21,700 | Germany (43%); Canada (23%); Netherlands (14%); Japan (4%); United Kingdom (4%); Mexico (3%). |
| 2833.23.0000 | Chromium sulfates | 532,000 | 1,540 | 11,100 | 145 | Japan (74%); Germany (15%); China (9%); Korea, Republic of (2%). |
| | Salts of oxometallic or peroxometallic acids: | | | | | |
| 2841.20.0000 | Zinc and lead chromate | 156,000 | 640 | 267,000 | 943 | Canada (27%); Dominican Republic (24%); Saudi Arabia (21%); Ireland (7%); United Kingdom (7%); Mexico (4%). |
| 2841.30.0000 | Sodium dichromate | 23,100,000 | 19,600 | 25,200,000 | 21,000 | Mexico (48%); Thailand (13%); Uruguay (10%); Columbia (7%); China (4%). |
| 2841.40.0000 | Potassium dichromate | 101,000 | 204 | 137,000 | 439 | Canada (47%); Brazil (23%); Israel (19%); Japan (8%); Australia (1%). |
| 2841.50.0000 | Other chromates, dichromates, and peroxochromates | 313,000 | 1,160 | 323,000 | 1,060 | Canada (74%); Mexico (15%); India (5%); Singapore (2%); Japan (2%). |
| 3206.20.0000 | Pigments and preparations, gross weight | 3,790,000 | 13,100 | 2,310,000 | 8,170 | Canada (47%); Mexico (23%); South Africa (9%); Costa Rica (4%); Germany (2%). |

1/ Data are rounded to three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States of America code.
3/ Articles thereof and waste and scrap.
4/ More than 4% carbon.
5/ Not more than 4% carbon.

Source: Bureau of the Census.

TABLE 10
U.S. IMPORTS FOR CONSUMPTION OF CHROMITE ORE, BY COUNTRY 1/

| Country | Not more than 40% $Cr_2O_3$ (HTSUSA 2/ 2610.00.0020) | | | More than 40% but less than 46% $Cr_2O_3$ (HTSUSA 2/ 2610.00.0040) | | | 46% or more $Cr_2O_3$ (HTSUSA 2/ 2610.00.0060) | | | Total | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gross weight (metric tons) | $Cr_2O_3$ content (metric tons) | Value (thou-sands) | Gross weight (metric tons) | $Cr_2O_3$ content (metric tons) | Value (thou-sands) | Gross weight (metric tons) | $Cr_2O_3$ content (metric tons) | Value (thou-sands) | Gross weight (metric tons) | $Cr_2O_3$ content (metric tons) | Value (thou-sands) |
| 1997: | | | | | | | | | | | | |
| Canada | -- | -- | -- | -- | -- | -- | 13 | 6 | $5 | 13 | 6 | $5 |
| China | 20 | 7 | $6 | -- | -- | -- | -- | -- | -- | 20 | 7 | 6 |
| Japan | 657 | 67 | 3 | -- | -- | -- | -- | -- | -- | 657 | 67 | 3 |
| Philippines | 5,780 | 1,910 | 1,050 | -- | -- | -- | -- | -- | -- | 5,780 | 1,910 | 1,050 |
| Russia | -- | -- | -- | -- | -- | -- | 22 | 261 | 117 | 22 | 261 | 117 |
| South Africa | 645 | 154 | 70 | 19,500 | 8,970 | $1,460 | 277,000 | 130,000 | 19,700 | 297,000 | 139,000 | 21,300 |
| Venezuela | 20 | 7 | 6 | -- | -- | -- | -- | -- | -- | 20 | 7 | 6 |
| Total | 7,120 | 2,140 | 1,140 | 19,500 | 8,970 | 1,460 | 277,000 | 130,000 | 19,900 | 303,000 | 141,000 | 22,500 |
| 1998: | | | | | | | | | | | | |
| Belarus | -- | -- | -- | -- | -- | -- | 117 | 55 | 76 | 117 | 55 | 76 |
| Canada | 9 | 4 | 4 | -- | -- | -- | -- | -- | -- | 9 | 4 | 4 |
| India | 12 | 4 | 5 | -- | -- | -- | -- | -- | -- | 12 | 4 | 5 |
| New Caledonia | -- | -- | -- | -- | -- | -- | 66 | 31 | 1 | 66 | 31 | 1 |
| Philippines | 5,290 | 2,120 | 576 | -- | -- | -- | 362 | 170 | 96 | 5,650 | 2,290 | 672 |
| Saudi Arabia | -- | -- | -- | -- | -- | -- | 24 | 12 | 3 | 24 | 12 | 3 |
| South Africa | -- | -- | -- | 89 | 40 | 13 | 352,000 | 169,000 | 25,500 | 352,000 | 169,000 | 25,600 |
| Total | 5,310 | 2,120 | 585 | 89 | 40 | 13 | 352,000 | 170,000 | 25,700 | 358,000 | 172,000 | 26,300 |

1/ Data are rounded to not more than three significant digits; may not add to totals shown.
2/ Harmonized Tariff Schedule of the United States of America code.

Source: Bureau of the Census.

TABLE 11
U.S. IMPORTS FOR CONSUMPTION OF FERROCHROMIUM, BY COUNTRY 1/

| Country | Low-carbon (not more than 3% carbon) (HTSUSA 2/ 7202.49.5000) Gross weight (metric tons) | Low-carbon Chromium content (metric tons) | Low-carbon Value (thousands) | Medium-carbon (more than 3% carbon but not more than 4% carbon) (HTSUSA 2/ 7202.49.1000) Gross weight (metric tons) | Medium-carbon Chromium content (metric tons) | Medium-carbon Value (thousands) | High-carbon (more than 4% carbon) (HTSUSA 2/ 7202.41.0000) Gross weight (metric tons) | High-carbon Chromium content (metric tons) | High-carbon Value (thousands) | Total (all grades) Gross weight (metric tons) | Total Chromium content (metric tons) | Total Value (thousands) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997: | | | | | | | | | | | | |
| Albania | -- | -- | -- | -- | -- | -- | 2,510 | 1,520 | $1,350 | 2,510 | 1,520 | $1,350 |
| Canada | -- | -- | -- | -- | -- | -- | 28 | 14 | 21 | 28 | 14 | 21 |
| China | 2,900 | 1,910 | $3,300 | 17 | 11 | $16 | 15,100 | 9,530 | 9,630 | 18,100 | 11,400 | 12,900 |
| Croatia | -- | -- | -- | -- | -- | -- | 12,200 | 7,880 | 6,540 | 12,200 | 7,880 | 6,540 |
| Germany | 10,500 | 7,320 | 26,700 | -- | -- | -- | -- | -- | -- | 10,500 | 7,320 | 26,700 |
| India | -- | -- | -- | -- | -- | -- | 11,200 | 7,010 | 6,880 | 11,200 | 7,010 | 6,880 |
| Japan | 281 | 110 | 520 | -- | -- | -- | -- | -- | -- | 281 | 110 | 520 |
| Kazakhstan | 1,300 | 845 | 1,560 | -- | -- | -- | 268 | 197 | 456 | 1,570 | 1,040 | 2,010 |
| Macedonia | 21 | 15 | 15 | -- | -- | -- | -- | -- | -- | 21 | 15 | 15 |
| Russia | 30,700 | 20,900 | 38,800 | 214 | 139 | 248 | 76,100 | 34,800 | 50,100 | 107,000 | 55,800 | 89,100 |
| South Africa | 10,200 | 5,780 | 7,880 | 1,300 | 671 | 568 | 112,000 | 55,300 | 48,600 | 124,000 | 61,700 | 57,100 |
| Sweden | 20 | 14 | 34 | -- | -- | -- | -- | -- | -- | 20 | 14 | 34 |
| Turkey | 100 | 73 | 164 | -- | -- | -- | 52,700 | 35,700 | 32,900 | 52,800 | 35,800 | 33,100 |
| United Kingdom | (3/) | (3/) | 2 | 22 | 12 | 9 | 82 | 56 | 63 | 104 | 68 | 74 |
| Zimbabwe | 3,020 | 2,030 | 3,510 | -- | -- | -- | 48,500 | 30,400 | 29,500 | 51,500 | 32,500 | 33,000 |
| Total | 59,100 | 39,000 | 82,500 | 1,550 | 834 | 842 | 331,000 | 182,000 | 186,000 | 392,000 | 222,000 | 269,000 |
| 1998: | | | | | | | | | | | | |
| Brazil | 20 | 13 | 45 | -- | -- | -- | -- | -- | -- | 20 | 13 | 45 |
| China | 3,220 | 2,090 | 3,430 | -- | -- | -- | 6,820 | 3,710 | 3,460 | 10,000 | 5,800 | 6,890 |
| Croatia | -- | -- | -- | -- | -- | -- | 6,150 | 3,920 | 3,280 | 6,150 | 3,920 | 3,280 |
| Germany | 8,770 | 6,100 | 19,800 | -- | -- | -- | 18 | 12 | 19 | 8,780 | 6,110 | 19,800 |
| India | -- | -- | -- | -- | -- | -- | 37,300 | 18,400 | 20,000 | 37,300 | 18,400 | 20,000 |
| Japan | 282 | 192 | 816 | -- | -- | -- | -- | -- | -- | 282 | 192 | 816 |
| Kazakhstan | 2,970 | 2,020 | 2,400 | 1,370 | 858 | 614 | 51,200 | 34,200 | 30,700 | 55,600 | 37,000 | 33,700 |
| Norway | -- | -- | -- | -- | -- | -- | 5,000 | 3,050 | 2,360 | 5,000 | 3,050 | 2,360 |
| Russia | 25,400 | 17,400 | 25,900 | -- | -- | -- | 41 | 25 | 21 | 25,400 | 17,400 | 25,900 |
| South Africa | 11,000 | 6,140 | 7,530 | -- | -- | -- | 163,000 | 83,000 | 66,600 | 174,000 | 89,100 | 74,100 |
| Sweden | 107 | 77 | 219 | -- | -- | -- | -- | -- | -- | 107 | 77 | 219 |
| Turkey | -- | -- | -- | -- | -- | -- | 43,700 | 27,100 | 24,000 | 43,700 | 27,100 | 24,000 |
| United Kingdom | 126 | 88 | 196 | -- | -- | -- | 16 | 10 | 10 | 142 | 98 | 206 |
| Zimbabwe | 1,940 | 1,300 | 1,750 | -- | -- | -- | 52,500 | 32,500 | 31,100 | 54,400 | 33,800 | 32,900 |
| Total | 53,800 | 35,400 | 62,100 | 1,370 | 858 | 614 | 366,000 | 206,000 | 182,000 | 421,000 | 242,000 | 244,000 |

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

2/ Harmonized Tariff Schedule of the United States of America code.

3/ Less than 1/2 unit.

Source: Bureau of the Census.

TABLE 12
U.S. IMPORTS FOR CONSUMPTION OF CHROMIUM MATERIALS, BY TYPE 1/

| HTSUSA 2/ | Type | 1997 Quantity (kilograms) | 1997 Value (thousands) | 1998 Quantity (kilograms) | 1998 Value (thousands) | Principal sources, 1998 |
|---|---|---|---|---|---|---|
| | Metals and alloys: | | | | | |
| | Chromium metal: | | | | | |
| 8112.20.3000 | Waste and scrap, gross weight | 23,700 r/ | $191 r/ | 9,530 | $72 | United Kingdom (50%); Germany (21%); Australia (17%); Mexico (5%); Russia (4%). |
| 8112.20.6000 | Other than waste and scrap, gross weight | 9,780,000 r/ | 72,400 r/ | 9,500,000 | 72,100 | Russia (26%); United Kingdom (25%); China (23%); France (22%). |
| 7202.50.0000 | Ferrochromium-silicon, gross weight | 36,500,000 | 23,700 | 20,000,000 | 12,500 | Russia (48%); Kazakhstan (35%); Zimbabwe (10%); China (8%). |
| 7202.50.0000 | Ferrochromium-silicon, contained weight | 14,700,000 | -- | 6,770,000 | -- | |
| | Chemicals: (gross weight) | | | | | |
| | Chromium oxides and hydroxides: | | | | | |
| 2819.10.0000 | Chromium trioxide | 2,980,000 | 5,930 | 4,220,000 | 7,900 | Kazakhstan (86%); Italy (6%); Poland (4%); Japan (3%). |
| 2819.90.0000 | Other | 3,550,000 | 13,800 | 4,890,000 | 14,500 | Japan (26%); Canada (24%); Germany (20%); Italy (9%); China (8%). |
| 2833.23.0000 | Sulfates of chromium | 216,000 | 212 | 447,000 | 395 | Germany (39%); United Kingdom (34%); Mexico (12%); South Africa (5%); Poland (4%); Turkey (4%). |
| | Salts of oxometallic or peroxometallic acids: | | | | | |
| 2471.20.0000 | Chromates of lead and zinc | 295,000 | 686 | 137,000 | 336 | Poland (35%); Norway (33%); Colombia (13%); France (10%); China (9%). |
| 2841.30.0000 | Sodium dichromate | 6,140,000 | 5,740 | 9,130,000 | 8,150 | United Kingdom (93%); Argentina (4%); Canada (2%); Turkey (1%). |
| 2841.40.0000 | Potassium dichromate | 350,000 | 688 | 478,000 | 612 | Netherlands (42%); United Kingdom (26%); Poland (15%); India (12%); Mexico (3%). |
| 2841.50.0000 | Other chromates and dichromates; peroxochromates | 788,000 | 1,720 | 657,000 | 1,410 | United Kingdom (96%); Australia (2%); Canada (1%); France (1%). |
| 2849.90.2000 | Chromium carbide | 160,000 | 2,110 | 167,000 | 2,200 | Japan (56%); United Kingdom (24%); Germany (20%). |
| | Pigments and preparations based on chromium: (gross weight) | | | | | |
| 3206.20.0010 | Chrome yellow | 6,820,000 | 19,500 | 6,420,000 | 18,400 | Canada (56%); Korea, Republic of (14%); Hungary (13%); Mexico (8%); China (7%). |
| 3206.20.0020 | Molybdenum orange | 1,760,000 | 6,420 | 2,050,000 | 7,900 | Canada (95%); Japan (3%); Spain (1%). |
| 3206.20.0030 | Zinc yellow | -- | -- | 4,170 | 7 | Colombia (100%). |
| 3206.20.0050 | Other | 1,090,000 | 4,560 | 1,030,000 | 3,910 | France (53%); South Africa (13%); China (9%); Germany (9%); Japan (5%); Colombia (4%); Mexico (4%). |

r/ Revised.

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

2/ Harmonized Tariff Schedule of the United States of America code.

Source: Bureau of the Census.

TABLE 13
PRINCIPAL WORLD CHROMITE ORE PRODUCERS, 1998

| Country 1/ | Company |
|---|---|
| Albania | Albkrom (Government owned). |
| Brazil | Cia. de Ferro Ligas da Bahia S.A. |
| | Elkem ASA (Norway). |
| | Mineracão Vila Nova Ltda. |
| | Magnesita S.A. |
| China | Huazang Smelter. |
| | Shashen. |
| | Xizang Kangjinla. |
| Finland | Outokumpu Oy. |
| | Outokumpu Steel Oy. |
| | Outokumpu Chrome Oy. |
| India | Ferro Alloys Corporation Ltd. |
| | Indian Charge Chrome Ltd. |
| | Misrilall Mines Ltd. |
| | Mysore Mineral Ltd. |
| | Orissa Mining Corporation Limited. |
| | The Tata Iron and Steel Co. Ltd. |
| Indonesia | PT. Palabim Mining-PT. Bituminusa. |
| Iran | Faryab Mining Company. |
| Kazakhstan | Donskoy Ore Dressing Complex. |
| Madagascar | Kraomita Malagasy. |
| Oman | Oman Chromite Company SAOG. |
| Philippines | Acoje Mining Co. Inc. |
| | Benguet Corporation. |
| | Heritage Resources & Mining Corporation. |
| | Krominco Inc. |
| | Philchrome Mining Corp. |
| | Velore Mining Corporation. |
| Russia | Saranov Complex. |
| South Africa | ASA Metals (Pty.) Ltd. |
| | African Mining and Trust Co. Ltd. |
| | Rustenburg Minerals Development Co. (Pty.) Ltd. |
| | Zeerust Chrome Mine Ltd. |
| | Bafokeng Chrome Holdings. |
| | Bayer AG (Germany). |
| | Bayer (Pty.) Ltd. |
| | Canadian Gold S.A. (Pty.) Ltd. |
| | Goudini Chrome (Pty.) Ltd. |
| | Hernic Ferrochrome (Pty.) Ltd. |
| | National Manganese Mines Pty. Ltd. |
| | Pilanesberg Chrome (Pty.) Ltd. |
| | Rooderand Chrome Mine (Pty.) Ltd. |
| | Rustenburg Minerals Development Company. |
| | Samancor Limited. |
| | Eastern Chrome Mines. |
| | Western Chrome Mines. |
| | Südelektra Holdings AG (Switzerland). |
| | Suedelektra SA. |
| | Chromecorp Pty. Ltd. |
| | Consolidated Metallurgical Industries Ltd. |
| | Vereeniging Refractories Ltd. |
| | Bophuthatswana Chrome Co. (Pty.) Ltd. |
| | Marico Chrome Corp. (Pty.) Ltd. |
| Sudan | Advanced Mining Works Co. Ltd. |
| Turkey | Aycan Madencilik Ltd. Sti. |
| | Bilfer Madencilik A.S. |
| | Birlik Madencilik Dis Tic. Insaat San. ve Tic. A.S. |
| | Cevher Madencilik ve Ticaret A.S. |
| | Dedeman Madencilik Sanayi ve Ticaret A.S. |
| | Etiholdings A.S. General Management (Government owned). |
| | Hayri Ögelman Mining Co. Ltd. |
| | Tekfen Dis. Ticaret A.S. |
| | Tevfik Refik Bayoglu Madencilik. |
| | Tut. Gen. Ticaret Ltd. Sti. |
| | Türk Maadin Sirketi A.S. |

See footnote at end of table.

TABLE 13--Continued
PRINCIPAL WORLD CHROMITE ORE PRODUCERS, 1998

| Country 1/ | Company |
|---|---|
| United Arab Emirates | Derkek Raphael & Co. |
| | Dewent Mining Ltd. |
| Zimbabwe | Zimasco (Pvt.) Ltd. |
| | Zimbabwe Alloys Ltd. |

1/ Other chromite-producing countries included Burma, Cuba, Pakistan, and Vietnam.

TABLE 14
PRINCIPAL WORLD FERROCHROMIUM PRODUCERS, 1998

| Country 1/ | Company |
|---|---|
| Albania | Albkrom (Government owned). |
| Brazil | Cia. de Ferro Ligas da Bahia S.A. |
| Chile | Carbomet Industrial SA. |
| China | Chongqing Ferro-Alloy Co. Ltd. (Government owned). |
| | Dandong Ferro-Alloy Plant. |
| | Dongfeng Ferro-Alloy Group Corp. |
| | Emei Ferroalloy Joint-Stock Co. Ltd. |
| | Hanzhong Ferroalloy Works (Government owned). |
| | Huazang Smelter. |
| | Hunan Ferro-Alloy (Government owned). |
| | Jiangyin Ferroalloy Factory (Government owned). |
| | Jilin Ferroalloy Works (Government owned). |
| | Jilin Huinan Ferroally Works. |
| | Jinzhou Ferro-Alloy (Group) Co. Ltd. |
| | Lengshuijiang Electrochemical Works. |
| | Liaoyang Ferroalloy Group Corp. |
| | Nanjing Ferroalloy Plant (Government owned). |
| | Ningjon Metal Smelting Co. Ltd. |
| | Shanghai Shenjia Ferro-Alloys Co. Ltd. |
| | Taonan Ferroalloy Works. |
| | Urad Zhongqi Ferrochrome Group Corp. |
| | Xibei Ferroalloy Works (Government owned). |
| | Zhejiang Hengshan Ferroalloy Works. |
| | Zunyi Ferroalloy Co. Ltd. |
| | Zunyi Ferroalloy General Factory. |
| Croatia | Dalmacija Ferro-Alloys Works. |
| Finland | Outokumpu Oy. |
| | Outokumpu Steel Oy. |
| | Outokumpu Chrome Oy. |
| Germany | Elektrowerk Weisweiler GmbH. |
| India | Andhra Ferro Alloys Limited. |
| | Baheti Metal & Ferro-Alloys Ltd. |
| | Bharat Thermite Ltd. |
| | Deepak Ferro-Alloys Ltd. |
| | Eastern Metals & Ferro-Alloys Ltd. |
| | Ferro Alloys Corp. Ltd. |
| | Charge Chrome Plant. |
| | Ferro-Alloys Unit. |
| | GMR Vasavi Industries Ltd. |
| | Hi-Tech Electrothermics Ltd. |
| | Indian Metals and Ferro Alloys Ltd. |
| | Indian Charge Chrome Ltd. |
| | Industrial Development Corp. |
| | Ispat Alloys Ltd. |
| | Jindal Strips Ltd. |
| | Ferro Alloys Division. |
| | Mandsaur Ferro Alloys Ltd. |
| | Metramet Ferroalloys Pvt. Ltd. |
| | Monnet Industries Ltd. |
| | Nav Chrome Limted. |
| | Nava Bharat Ferro Alloys Ltd. |
| | Raghuvir Ferro Alloy Pvt. Ltd. |
| | Shri Girija Smelters Limited. |
| | Srinivasa Ferro Alloys Ltd. |
| | Standard Chrome Ltd. |
| | The Sandur Manganese & Iron Ores Ltd. |
| | The Tata Iron and Steel Company Ltd. |
| | Bamnipal Plant. |
| | Joda Plant. |
| | VBC Ferro Alloys Ltd. |
| | V.K. Ferro Alloys Private Ltd. |
| Iran | Faryab Mining Co. |
| | Abadan Ferroalloys Refinery. |
| Italy | Darfo S.p.A. |
| | Fornileghe S.p.A. |
| | Mineralsider S.p.A. |

See footnote at end of table.

TABLE 14--Continued
PRINCIPAL WORLD FERROCHROMIUM PRODUCERS, 1998

| Country 1/ | Company |
|---|---|
| Japan | Japan Metals and Chemicals Co. Ltd. |
| | Nippon Denko Co., Ltd. |
| | NKK Corporation. |
| | Showa Denko K.K. |
| Kazakhstan | Aksusky Ferroalloy Plant. |
| | Aktyubinsk Ferroalloy Plant. |
| Macedonia | Jugochrom. |
| Norway | Elkem ASA. |
| Philippines | Araneta Properties. |
| | Ferrochrome Philippines Inc. |
| | Philippines Minerals & Alloy Corporation. |
| Poland | Huta "Laziska" Ferroalloy Plant. |
| Romania | S.C. Ferom S.A. |
| Russia | Chelyabinsk Electrometallurgical Integrated Plant. |
| | Klutchevsk Ferroalloy Plant. |
| | Metall Joint Venture. |
| | Serov Ferroalloys Plant. |
| Slovakia | Oravske Ferozliatinarske Zavody. |
| Slovenia | Tovarna Dusika Ruse-Metalurgija d.d. |
| South Africa | Associated Manganese Mines of South Africa Ltd. |
| | Feralloys Ltd. |
| | Hernic Ferrochrome (Pty.) Ltd. |
| | Samancor Limited. |
| | Batlhako Ferrochrome Ltd. |
| | Ferrometals Division. |
| | Middelburg Ferrochrome Division. |
| | Palmiet Ferrochrome Division. |
| | Tubatse Ferrochrome Division. |
| | Südelektra Holdings A.G. (Switzerland). |
| | Suedelektra SA. |
| | Chromecorp (Pty.) Ltd. |
| | Consolidated Metallurgical Industries Ltd. |
| | Lydenburg Works. |
| | Rustenburg Works. |
| | Purity Ferrochrome (Pty.) Ltd. |
| Sweden | Vargön Alloy AB. |
| Turkey | Etiholdings As. General Management (Government owned). |
| | Antalya Works. |
| | Elazig Works. |
| Ukraine | Zaporozhye Ferro-Alloy Works. |
| United States | Elkem Metals Co. |
| | Macalloy Corp. |
| Zimbabwe | Zimasco Private Ltd. |
| | Zimbabwe Alloys Ltd. |

1/ Other ferrochromium-producing countries include Spain, and Taiwan.

TABLE 15
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

| Country 3/ | 1994 | 1995 | 1996 | 1997 | 1998 e/ |
|---|---|---|---|---|---|
| Albania | 118,000 | 160,000 | 143,000 | 106,000 e/ | 100,000 |
| Brazil 4/ | 359,788 | 447,963 | 408,495 | 300,000 r/ | 330,000 |
| Burma e/ | 1,000 | 1,000 | 1,000 | 1,000 | 5,000 |
| China e/ | 62,000 | 94,000 | 130,000 | 120,000 | 150,000 |
| Cuba | 20,000 | 30,693 | 37,300 | 44,000 | 50,000 |
| Finland | 572,747 | 597,605 | 573,904 | 589,000 r/ | 611,000 |
| Greece | 5,000 e/ | 5,000 e/ | 11,725 r/ | 12,020 r/ | 12,000 |
| India | 909,076 | 1,536,386 | 1,363,205 | 1,363,049 | 1,360,000 |
| Indonesia e/ | 2,500 | 10,000 | 13,300 | 2,156 5/ | 2,000 |
| Iran | 354,100 | 371,100 | 250,000 | 200,000 | 200,000 |
| Japan | -- r/ | -- r/ | -- r/ | -- r/ | -- |
| Kazakhstan | 2,103,000 r/ | 2,417,000 r/ | 1,190,000 r/ | 1,800,000 r/ | 1,600,000 |
| Macedonia e/ | 5,000 | 5,000 | 5,000 | 5,000 | 5,000 |
| Madagascar | 90,200 | 106,107 | 137,210 | 139,700 | 130,000 |
| Oman | 6,166 | 5,300 | 15,000 | 15,000 e/ | 15,000 |
| Pakistan | 6,240 | 17,000 e/ | 27,987 | 30,000 e/ | 29,000 |
| Philippines | 76,003 | 111,035 | 78,345 | 87,500 | 87,000 |
| Russia | 143,000 | 151,400 | 96,700 | 150,000 e/ | 130,000 |
| South Africa | 3,642,000 r/ | 5,104,000 r/ | 5,017,000 r/ | 5,740,000 r/ | 5,500,000 |
| Sudan e/ | 25,000 | 44,988 5/ | 15,000 r/ | 10,000 r/ | 10,000 |
| Turkey | 1,270,431 | 2,080,043 | 1,279,032 | 1,863,878 r/ | 1,600,000 |
| United Arab Emirates | 55,000 | 37,000 | 56,000 | 61,000 e/ | 65,000 |
| Vietnam | 63,000 | 91,000 | 35,000 e/ | 35,000 e/ | 35,000 |
| Zimbabwe | 516,801 | 707,433 | 697,311 | 670,000 r/ e/ | 660,000 |
| Total | 10,400,000 r/ | 14,100,000 r/ | 11,600,000 r/ | 13,300,000 r/ | 12,700,000 |

e/ Estimated. r/ Revised.
1/ World totals and estimated data are rounded to three significant digits; may not add to totals shown.
2/ Table includes data available through June 25, 1999.
3/ Figures for all countries represent marketable output unless otherwise noted.
4/ Average $Cr_2O_3$ content was as follows: 1994--41.3%; 1995-96--42.2%; 1997--37.4% (revised); and 1998--34.5% (estimated).
5/ Reported figure.

TABLE 16

FERROCHROMIUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

| Country | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|
| Albania | 33,764 | 42,986 | 31,189 | 31,454 r/ | 29,960 |
| Brazil 3/ | 77,105 r/ | 100,969 r/ | 77,231 r/ | 112,274 r/ | 110,000 e/ |
| Chile | 1,579 | 2,730 | 2,700 r/ | 2,000 r/ | 2,000 e/ |
| China e/ | 370,000 | 500,000 | 423,000 | 480,000 r/ | 424,000 |
| Croatia | 31,704 | 26,081 | 10,559 | 24,231 | 11,770 |
| Finland | 253,501 | 246,805 | 227,811 | 236,652 r/ | 230,906 |
| Germany | 17,283 | 21,665 | 25,303 | 25,856 | 20,879 |
| India 4/ | 251,459 r/ | 303,537 r/ | 261,666 | 286,973 | 345,125 |
| Iran | 7,150 | 11,900 | 10,500 | 11,450 | 13,745 |
| Italy | 22,650 | 51,017 | 29,915 | 11,295 | 11,487 |
| Japan 3/ | 192,989 r/ | 210,445 r/ | 193,695 r/ | 186,432 r/ | 142,931 |
| Kazakhstan | 373,300 r/ | 511,600 r/ | 352,000 | 600,000 r/ | 535,000 |
| Macedonia | 3,164 | 3,765 | 3,780 | 460 | -- |
| Norway | 120,000 | 148,000 | 108,900 r/ | 145,124 r/ | 170,000 |
| Philippines | 16,186 | 50,450 | 6,736 | -- | -- e/ |
| Poland | 7,353 | 18,334 | 3,785 | 5,900 | 3,600 |
| Romania | 3,885 | 15,053 | 9,650 | 950 | 850 |
| Russia e/ | 265,525 5/ | 290,000 | 135,000 | 247,000 | 203,000 5/ |
| Slovakia 3/ | 48,555 | 65,260 | 19,900 | 11,394 | 11,715 |
| Slovenia | 13,412 | 23,247 | 22,819 | 9,232 | 10,621 |
| South Africa 6/ | 1,103,612 | 1,341,000 r/ | 1,478,000 | 1,890,000 r/ | 2,184,974 |
| Spain | 2,300 | 1,320 | 805 | 490 | 1,145 |
| Sweden | 134,076 | 130,170 | 138,110 | 101,842 | 123,958 |
| Turkey | 97,585 | 94,251 | 101,450 | 108,726 r/ | 89,570 |
| United States 7/ | 67,400 | 72,500 | 36,800 | 60,700 | W |
| Zimbabwe 3/ | 182,852 | 254,142 | 243,000 r/ | 233,386 r/ | 246,782 |
| Total | 3,700,000 r/ | 4,540,000 r/ | 3,950,000 r/ | 4,820,000 r/ | 4,920,000 |

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data; not included in "Total."

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 June 25,1999.

3/ Includes high- and low-carbon ferrochromium.

4/ Includes ferrochrome and charge chrome.

5/ Reported figure.

6/ Includes high- and low-carbon ferrochromium and ferrochromium-silicon.

7/ Includes high- and low-carbon ferrochromium, ferrochromium-silicon, chromium metal, and other chromium r

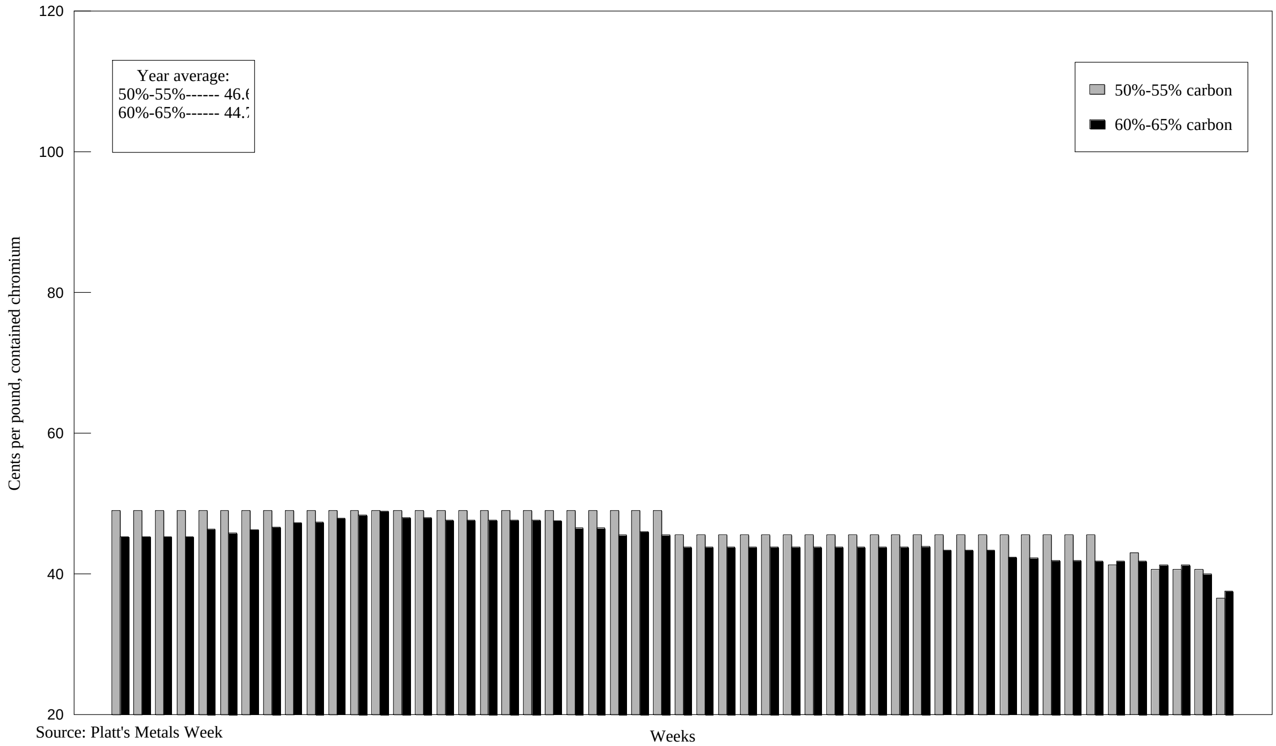
TABLE 17
WORLD CHROMIUM ANNUAL PRODUCTION CAPACITY OF CHROMITE ORE,
FERROCHROMIUM, CHROMIUM METAL, CHROMIUM CHEMICALS, AND STAINLESS STEEL IN 1998 1/

(Thousand metric tons, contained chromium)

| | Ore | Ferro-chromium | Metal | Chemicals | Stainless steel |
|---|---|---|---|---|---|
| Albania | 60 | 25 | -- | -- | -- |
| Argentina | -- | -- | -- | 6 | -- |
| Austria | -- | -- | -- | -- | 8 |
| Bangladesh | -- | -- | -- | -- | 3 |
| Belgium | -- | -- | -- | -- | 107 |
| Brazil | 135 | 66 | -- | -- | 46 |
| Burma | 1 | -- | -- | -- | -- |
| Canada | -- | -- | -- | -- | 32 |
| Chile | -- | 2 | -- | -- | -- |
| China | 25 | 325 | 6 | 21 | 68 |
| Croatia | -- | 16 | -- | -- | -- |
| Cuba | 14 | -- | -- | -- | 7 |
| Egypt | -- | -- | -- | -- | -- |
| Finland | 211 | 134 | -- | -- | 99 |
| France | -- | -- | 7 | -- | 187 |
| Germany | -- | 20 | 1 | -- | 255 |
| Greece | 4 | -- | -- | -- | -- |
| India | 480 | 220 | (2/) | 8 | 111 |
| Indonesia | 20 | -- | -- | -- | -- |
| Iran | 130 | 10 | -- | 2 | -- |
| Italy | -- | 34 | -- | -- | 182 |
| Japan | -- | 89 | 1 | 17 | 660 |
| Kazakhstan | 750 | 567 | 1 | 42 | -- |
| Korea, Republic of | -- | -- | -- | -- | 204 |
| Macedonia | 2 | 3 | -- | 5 | -- |
| Madagascar | 45 | -- | -- | -- | -- |
| Mexico | -- | -- | -- | -- | -- |
| Norway | -- | 106 | -- | -- | -- |
| Oman | 6 | -- | -- | -- | -- |
| Pakistan | 10 | -- | -- | 3 | -- |
| Philippines | 38 | 28 | -- | -- | -- |
| Poland | -- | 16 | -- | 5 | -- |
| Romania | -- | 33 | -- | 9 | -- |
| Russia | 40 | 207 | 14 | 60 | 330 |
| Slovakia | -- | 56 | -- | -- | -- |
| Slovenia | -- | 13 | -- | -- | 13 |
| South Africa | 1,700 | 1,250 | -- | 24 | 95 |
| Spain | -- | -- | -- | -- | 140 |
| Sudan | 14 | -- | -- | -- | -- |
| Sweden | -- | 113 | -- | -- | 128 |
| Taiwan | -- | 1 | -- | -- | 165 |
| Thailand | -- | -- | -- | -- | -- |
| Turkey | 580 | 100 | -- | 10 | 54 |
| Ukraine | -- | -- | -- | -- | 33 |
| United Arab Emirates | 21 | -- | -- | -- | -- |
| United Kingdom | -- | -- | 7 | 52 | 92 |
| United States | -- | 20 | 3 | 56 | 390 |
| Vietnam | 10 | -- | -- | -- | -- |
| Zimbabwe | 214 | 156 | -- | -- | -- |
| Total | 4,510 | 3,610 | 40 | 320 | 3,410 |

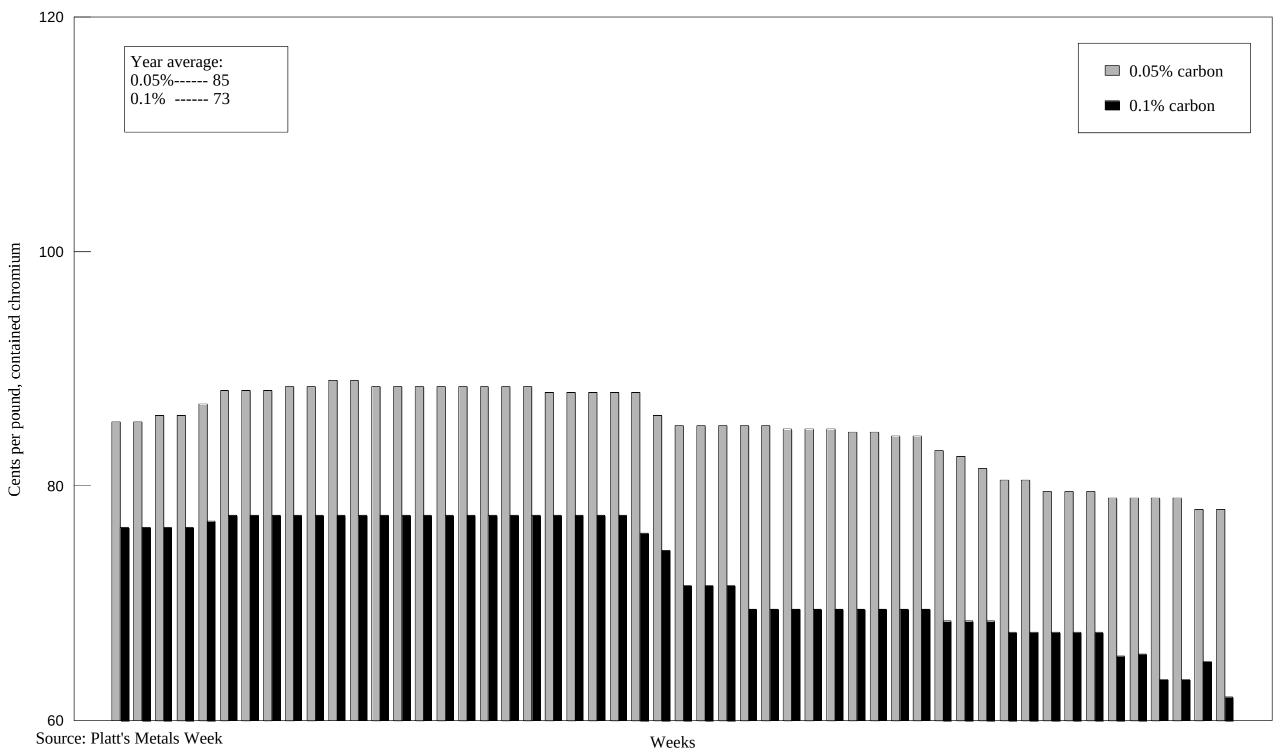
1/ Data are rounded to not more than three significant digits; may not add to totals shown.
2/ Less than 1/2 unit.

FIGURE 1
U.S. IMPORTED HIGH-CARBON FERROCHROMIUM, AVERAGE WEEKLY PRICES IN 1998



Source: Platt's Metals Week

FIGURE 2
U.S. IMPORTED LOW-CARBON FERROCHROMIUM, AVERAGE WEEKLY PRICES IN 1998



Source: Platt's Metals Week