CHROMIUM

By John F. Papp

In 1994, chromium apparent consumption was 390,000 tons of contained chromium. U.S. supply consisted of recycled and imported chromium materials. The United States recycled about 582,000 tons, gross weight, of stainless steel scrap and imported about 567,000 tons of chromite ore, ferroalloys, chemicals, and pigments valued at about $254 million. The United States exported about 90,300 tons of chromium materials valued at about $70 million. Compared with those of 1993, both quantity and value of chromium materials trade decreased in 1994. *(See table 1.)*

Because the United States has no chromite ore reserves and a limited 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. The National Defense Stockpile (NDS) contains chromium in various forms, including chromite ore, chromium ferroalloys, and chromium metal in recognition of the vulnerability of long supply routes during a military emergency. Recycling is the only domestic supply source of chromium. As a result of reduced threat to the territory of the United States, stockpile goals have been reduced and may be reduced further.

Research is conducted by the Federal Government to reduce U.S. vulnerability to potential chromium supply interruption. That research covers both domestic resource utilization and alternative materials identification. Domestic chromium resources include mineral deposits and recyclable materials. The U.S. Bureau of Mines (USBM) evaluates the development potential of U.S. chromium mineral deposits. The USBM also studies minerals extraction and processing and materials substitution and recycling. Alternative materials research also is conducted by the National Aeronautics and Space Administration, the National Institute of Standards and Technology, the Department of Defense, and the Department of Energy.

World chromite ore reserves are more than adequate to meet anticipated world demand. Operation and transportation are the two major components of chromite ore cost in the marketplace.

Chromium is an essential trace element for human health. However, some chromium compounds are acutely toxic, chronically toxic, and/or carcinogenic. Chromium releases into the environment are regulated by the Environmental Protection Agency (EPA). Workplace exposure is regulated by the Occupational Safety and Health Administration (OSHA).

Legislation and Government Programs

Dissolution of the Soviet Union into the Confederation of Independent States and other independent states at the end of 1991 resulted in the reevaluation of the NDS. The absence of a single large adversary encouraged many to advocate reduction of the NDS. Others argued that history has demonstrated the need for a stockpile because periods of relative peace have been interspersed with conflict and that there is no reason to expect this pattern to change. Based on new international political conditions, the Defense Logistics Agency (DLA) submitted annual materials plans that identified chromium materials for disposal. The Revised Annual Materials Plan for Fiscal Year 1994 (as of September 30, 1994) identified chromite ore for disposal as follows: 45,400 tons of chemical grade, 318,000 tons of metallurgical grade, and 90,700 tons of refractory grade. The Annual Materials Plan for Fiscal Year 1995 identified chromite ore for disposal as follows: 45,400 tons of chemical grade and 318,000 tons of metallurgical grade. As part of the National Defense Authorization Act, DLA was prohibited from selling ferrochromium. DLA reported disposal of chromium materials during the October 1993 through September 1994 fiscal year. DLA reported disposal of 9,940 tons of refractorygrade chromite ore, 193,000 tons of metallurgical-grade chromite ore, and 39,000 tons of ferrochromium. (Disposal here means material set aside for sale, trade, or payment in kind. It does not mean material physically removed from the NDS.)[1] (See *Stocks* section.)

In accordance with the President's November 1982 directive and Public Law 99-591, the DLA continued to upgrade NDS chromite ore to high-carbon ferrochromium. The Agency reported conversion of chromite ore to ferrochromium on a contract year basis. DLA signed a contract with Macalloy Corp., Charleston, SC, in 1990 to upgrade NDS chromite ore. The contract period covers the years 1990–94. Macalloy converted 84,100 tons of chromite ore to about 30,800 tons ferrochromium for DLA during the 1994 contract year. The chromite ore to ferrochromium stockpile conversion program was completed in August 1994. *(See table 2.)*

As part of its plan to modernize the NDS, DLA contracted with Elkem Metals Co., Marietta, OH, to upgrade NDS nonspecification-grade low-carbon ferrochromium into electrolytic (vacuum melting-grade) chromium metal. Elkem converted low-carbon ferrochromium to 835 tons of chromium metal during the October 1993 and September 1994 contract period. The low-carbon ferrochromium to chromium metal conversion program was completed in August 1994. *(See table 3.)*

The OSHA reviewed personal exposure limits for chromium materials. OSHA planned to report the results of its review in 1995.

The U.S. Department of Health and Human Services, Public Health Service, Agency of Toxic Substances and Disease Registry published a fact sheet on chromium dated April 1993. They reported that exposure to chromium happens mostly from breathing workplace air or ingesting water or food from soil near waste sites. Chromium can damage the lungs and cause allergic responses in the skin. Chromium has been found in at least 115 of 1,300 National Priorities List sites identified by the EPA.

The EPA regulated the use and disposal of chromium containing materials. EPA banned the use chromium chemicals for industrial process water cooling towers for corrosion inhibition. It was reported that 90% of industrial cooling tower operators had eliminated the use of chromium chemicals in anticipation of such an EPA ban. However, the remaining 800 operations were given 18 months within which to comply with the new ruling.[2] EPA planned to promulgate air quality standards that require chromium electroplaters and anodizers to reduce its chromium emissions by 99% in 1995. EPA planned to give hard-chromium electroplaters and anodizers 2 years to comply and decorative chromium platers 1 year to comply with the new regulation. EPA collected emission data from U.S. ferrochromium producers as part of its

ferroalloy producer emission study. EPA planned to collect and analyze ferroalloy production process emission data to determine achievable and economic emission control levels for that industry. EPA planned to have an emission control proposal completed in 1995.

EPA reported chromium releases and transfers from manufacturing and fabrication facilities. *(See tables 4 and 5.)*

Production

The major marketplace chromium materials are chromite ore and chromium ferroalloys, metal, and chemicals. In 1994, the United States produced chromium ferroalloys, metal, and chemicals, but not chromite ore.

Domestic production data for chromium ferroalloys and metal are developed by the USBM by means of two separate surveys. They are the monthly "Chromite Ores and Chromium Products" and the annual "Ferroalloys." Production by the metallurgical companies listed in table 6 represented 100% of the domestic production shown in the current year of table 7.

Chrome Corp. of America continued development of its chromite property in Montana. Chrome Corp. planned to build a ferrochromium and chromium-nickel alloys plant in North America in a joint venture with FerroCarb Corp. under the name Canadian Steel and Alloys Corp. Chrome Corp. planned to use its Montana chromite resources as its source of chromium units. Chrome Corp. reported 14.6 million tons of chromite resources graded at 26% Cr_2O_3.

Cook Island Region Inc. (CIRI) continued development of its chromite deposit at Red Mountain near Seldovia, AK. CIRI contracted the University of Alaska Fairbanks to conduct smelting tests on Red Mountain chromite in preparation for economic feasibility studies.

JMC (USA) Inc., a subsidiary of Japan Metals and Chemicals Co., began production of high-purity chromium metal at Research Triangle Park, NC. JMC's annual production capacity was planned to reach 24 tons of 99.995% pure chromium metal produced by electrolysis in 1994. Production was planned to be exported to the parent company for use in the electronics industry.

Consumption

Domestic reported consumption of chromite ore and concentrate was 322,000 tons in 1994. Of the total chromite consumed, the chemical and metallurgical industry used 302,000 tons; the refractory industry, 20,100 tons. Domestic reported consumption of chromium ferroalloys and metal was 349,000 tons in 1994.

The metallurgical industry consumed chromite ore to make chromium ferroalloys that are subsequently used to add chromium to ferrous and nonferrous alloys. Stainless steel is the major end use of chromium ferroalloys. The chemical industry consumed chromite for manufacturing sodium bichromate, chromic acid, and other chromium chemicals and pigments. Sodium bichromate is the material from which a wide range of chromium chemicals are made. The primary use of chromium in the refractory industry was in the form of chromite to make refractory bricks to line metallurgical furnaces. *(See tables 8 and 9.)*

Stocks

Reported domestic consumer stocks of chromite ore at consumers' plants were 266,000 tons in 1994. At the 1994 annual rate of chromite ore consumption, consumer stocks represented 10 months of supply in the chemical and metallurgical industry and 10 months of supply in the refractory industry. Producer stocks of chromium ferroalloys, metal, and other chromium materials were 8,070 tons in 1994. Consumer stocks of chromium ferroalloys, metal, and other chromium materials were 14,900 tons in 1994. At the 1994 annual rate of chromium ferroalloy, metal, and other chromium material consumption, producer plus consumer stocks represented 0.8 month of supply. *(See table 10.)* The government maintained the NDS. *(See table 11.)* (See *Legislation and Government Programs* section.)

Prices

Chromium materials are not openly traded. Purchase contracts are confidential information between buyer and seller. However, trade journals report composite prices based on interviews with buyers and sellers and traders declare the value of materials they import or export. Thus industry publications and U.S. trade data are a source of chromium material prices and values, respectively. *(See tables 12, 13, 14, and 19, and figures 1 and 2.)*

Foreign Trade

Chromium material exports from and imports to the United States included chromite ore and chromium chemicals, ferroalloys, metal, and pigments. *(See tables 15 through 18.)*

World Review

The major world chromite ore producing countries are India, Kazakhstan, and South Africa. Brazil, Finland, Turkey, and Zimbabwe are significant chromite ore producing countries. Most chromite ore is smelted in an electric arc furnace to produce ferrochromium for use by the metallurgical industry. Stainless steel manufacture is the major end use of ferrochromium. A small amount of chromite is kiln roasted to produce sodium bichromate, a chemical industry product. A very small amount of chromite ore is used, without chemical modification, as a refractory material. The major ferrochromium producing countries are Kazakhstan, Russia, and South Africa. China, Finland, India, Japan, Sweden, and Zimbabwe are significant ferrochromium producing countries. The major stainless steel producing areas of the world, Europe (including Western Europe and Scandinavia), Japan, and the United States, account for about 70% of world stainless steel production. The major world chromium chemical producing countries are Kazakhstan, Russia, United Kingdom, and the United States. *(See tables 20 through 23.)*

Industry Structure.—The chromium industry is composed primarily of chromite ore producers, ferrochromium producers, and stainless steel producers. Other industry components are chromium chemical and chromite refractory producers. Brazil, Finland, India, Turkey, and the Republic of South Africa are countries that have vertically integrated chromium industry. They mine chromite ore, produce ferrochromium, and produce stainless steel. In Finland, Outokumpu Oy, a major share of which is stateowned, owns and operates the only chromite mining, ferrochromium production, and stainless steel production facilities, making it completely vertically integrated. In the Republic of South Africa, chromium-related companies are privately owned. Typically, major shares of a company are owned by other companies and the remainder, if any, is openly traded. Samancor owns and operates chromite mining and ferrochromium production, and co-owns the only stainless steel production facilities. In Brazil, the mining and smelting of chromium is vertically integrated, but stainless steel production is independent of the mining-smelting operations. The major mining companies are subsidiaries of Cia. de Ferro Ligas da Bahia S.A. Stainless steel is produced primarily by Companhia Acos Especiais Itabira. Other chromite operations in Brazil are also vertically integrated. Bayer AG (Germany) owns a chromite mine and chromium chemical plant. Refractory chromite operations are also

vertically integrated from chromite production through refractory material production. Chromite mining and ferrochromium production in India is mostly vertically integrated. Ferro Alloys Corp. is the only stainless steel producer in India that is integrated from chromite ore mining through ferrochromium and stainless steel production. In Japan and Russia, chromite ore production is minor and primarily for refractory industry use. In Japan, some ferrochromium producers are associated with stainless steel plants by location, ownership, or both. In Russia, production facilities are Government owned. In Kazakhstan, chromite ore mining and ferrochromium production is vertically integrated. In Turkey, the chromium industry is composed of both large and small chromite ore producers, with one major producer, Etibank, integrated from mining through ferrochromium production. The chromium industry of Zimbabwe is composed of large companies vertically integrated from chromite mine production through ferrochromium production, small independent chromite mines, and chromite mines operated independently on behalf of the large vertically integrated companies. In China, the chromium industry is concentrated on ferrochromium production. Only minor amounts of chromite ore and moderate amounts of stainless steel are produced in China.

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, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both 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 producers make production capacity information available, historical chromium trade data have been used to estimate production capacity. Rated production capacity changes result both from changes in facilities and changes in knowledge about facilities. Capacities have been rated for the chromite ore, ferrochromium, chromium chemical, and chromium metal industries. *(See table 24.)*

Reserves.—The United States has no chromite ore reserves. However, the United States has a reserve base and resources that could be exploited. Domestic and foreign reserve estimates are reported by the USBM in other publications.[3]

Production.—World chromite ore production in 1994 was about 9.6 million tons, a 3% increase over that of 1993. This increase follows 2 years of major decreases (down 22% from 1991 to 1992 and down 18% from 1992 to 1993). World ferrochromium production in 1994 was about 3.50 million tons, a 7% increase over that of 1993. This increase follows 2 years of substantial decline (down 5% from 1991 to 1992 and down 11% from 1992 to 1993). *(See tables 22 and 23.)*

***Albania.*—National.**—Albchrome, a semi-autonomous organization responsible for the chromite mining and ferrochromium production industry, was established in 1992 for the purpose encouraging private investment in the country's chromium industry. Albchrome negotiated with Metallgesellschaft and Mannesmann AG (Germany) and with Macalloy (United States) and a group of United Kingdom companies to develop a joint-venture partnership.

Chromite Ore.—Chromite ore production rates were reported by source in 1994 to have been: Batra, 100,000 tons per year; Bulqiza, 200,000 tons per year; and Kalimash, 200,000 tons per year at 20% to 22% Cr_2O_3. These production levels were about one-third of potential production rates. The chromite ore resources of Albania were reviewed. Based on capacity estimates by mine and grade by mine, Albania's run-of-mine production capacity was reported to be 1,515,000 tons, with a marketable product of about one-half that amount.[4]

Ferrochromium.—Albania also operated two ferrochromium plants, one at Burrel and one at Elbasan. Production was reported to have been 22,000 tons of high-carbon ferrochromium in 1992 and projected to reach 34,626 tons in 1993.

Australia.—Dragon Mining NL continued development of its Range Well lateritic chromiferous deposit in Western Australia. Dragon planned to use the high-iron content ore to product cast grinding balls by a direct casting and smelting route. Dragon Mining, Pyromet CC (South Africa), and Mintek (South Africa) produced and tested grinding balls from a sample of Range Well ore. The smelting and casting tests are the basis upon which furnace and plant, and capital and operating cost for Range Well are based.

***Brazil.*—National.**—Brazil imposed a 27.19% duty on imports of low-carbon ferrochromium from the Confederation of Independent States effective in April for a duration of 5 years subject to annual review. The duty replaced a provisional 18.97% duty. The duty was based on a request by Associação Brasileira Dos Produtores De Ferroligas (ABRAFE) made in November 1992.

Chromite Ore and Ferrochromium.—Cia Ferroligas do Amapa exported chromite in 1993. Companhia de Ferro-Ligas da Bahia S.A. produced chromite ore and smelted it into high- and low-carbon ferrochromium and ferrochromiumsilicon. Departamento Nacional da Produção Mineral reported chromite ore reserves in 1993 to have been 6,900,000 tons of average grade 30.0% Cr_2O_3, production in 1993 of chromite ore was 127,000 tons of contained Cr_2O_3; chromium ferroalloys and metal production, 86,759 tons; and chromium chemical production was 63,000 tons. Brazilian chromium apparent consumption in 1993 was about 140,000 tons of contained chromium, a 17% decrease from 170,000 tons reported for 1992.

***Canada.*—National.**—The government of Canada studied chromium in the environment. Concentrations of dissolved hexavalent chromium in several rivers and streams were found to exceed the effects threshold for most sensitive aquatic species. Environment Canada and Health and Welfare Canada concluded that dissolved and soluble forms of hexavalent chromium are entering or may enter the environment in a quantity or concentration or under conditions that are having or may have a harmful effect on the environment.

Chromite and Ferrochromium.—Ressources Minières Coleraine Inc. planned a high-carbon ferrochromium plant in Quebec. The company sought partners.

***China.*—National.**—China has assumed an increasingly important roll as a consumer of chromite ore and a producer of chromium ferroalloys and metal as shown by China's trade statistics since the late 1980's. China abolished a 10% export rebate on aluminothermic chromium metal.

China reported trade statistics for 1993–94. Chinese chromium trade has been dynamic. China imported chromite ore as follows: 429,808 tons in 1988; 595,783 tons in 1989; 641,268 tons in 1990; 544,649 tons in 1991; 901,021 tons in 1992; 618,757 tons in 1993; and 650,000 tons in 1994. The dramatic increase in Chinese imports of chromite ore reportedly resulted from the conversion of ferroalloy production capacity to ferrochromium partly for foreign sale. In 1993, China produced 345,000 tons of chromium ferroalloys distributed by grade as follows: 210,000 tons of high-carbon ferrochromium; 50,000 tons of medium-carbon ferrochromium; 65,000 tons of low-carbon ferrochromium; and 20,000 tons of ferrochromiumsilicon. From this production, China exported 145,000 tons of chromium ferroalloy distributed by grade as follows: 123,279 tons of high-carbon ferrochromium; 6,442 tons of medium- and low-carbon ferrochromium; and 14,950 tons of

ferrochromiumsilicon. China also exported 6,978 tons of chromium metal in 1993, an increase from exports of 6,720 tons in 1992. In 1994, China produced 350,000 tons of chromium ferroalloys distributed by grade as follows: 230,000 tons of high-carbon ferrochromium; 50,000 tons of medium-carbon ferrochromium; 35,000 tons of low-carbon ferrochromium; and 35,000 tons of ferrochromiumsilicon. Chinese stainless steel production was estimated to have been about 300,000 tons in 1993 accounting for about 200,000 tons of domestic ferrochromium consumption. China anticipated its local demand for ferrochromium will increase to 400,000 tons by the year 2000 as a result of growth in domestic stainless steel production to about 800,000 tons in 2000. Chinese chromium apparent consumption was about 130,000 tons in 1993.

Chromite Ore.—The Dongfeng Mine in northern Tibet started chromite ore production in 1967. Since opening, Dongfeng has produced 420,000 tons of chromite. Development of the Luobusa mining complex in south central Tibet started in 1988 and reached opencast production design capacity in 1994. A beneficiation plant is being constructed and plans for underground mining were being made. The complex consists of four mines, two operated by the local government and two operated by cooperatives. Chromite ore annual production capacity was about 50,000 tons and was expected to rise to 130,000 tons when mine construction is complete; run-of-mine ore graded at 45% Cr_2O_3.

Ferrochromium.—China shifted ferroal-loy production capacity to ferrochromium production resulting in a greater role for China in chromite ore and ferrochromium markets starting in 1991. As a result, China's ferrochromium exports grew from 8,000 tons in 1987 to 145,000 tons in 1993. Ferrochromium producers in China were reported to have been: Chongqing, Sichuan Province; Emei, Sichuan Province; Hanzhong, Shanxi Province; Hengshan, Zhejiang Province; Hunan, Hunan Province; Jiangyin, Jiangsu Province; Jilin, Jilin Province; Jinzhou, Liaoning Province; Liaoyang, Liaoning Province; Nanjing, Jiangsu Province; Shanghai, Shanghai Municipality; and Xibei, Gansu Province.

Croatia.—Dalmacija Dugi Rat operated a high-carbon ferrochromium smelter composed of three, 20 megawatt furnaces to produce high-carbon ferrochromium containing over 65% chromium with an annual production capacity in the range of 105,000 to 110,000 tons. Dalmacija closed operation in August 1994 owing to insufficient power supply.

Cuba.—Cuba studied the potential of producing high-carbon ferrochromium and ferrochromiumsilicon from Cuban ore graded at 34% Cr_2O_3.

Finland.—The chromium industry of Finland is vertically integrated from chromite ore mining through stainless steel production under Outokumpu Steel Oy. The Kemi chromite deposit was discovered in 1959 followed by a decision to mine in 1964 and industrial scale production in 1968. It is 7 kilometers northeast of Kemi City. Reserves were reported at 70 million tons with resources at 150 million tons of ore. Ore grade is 26% Cr_2O_3 average grade. The ferrochromium plant started production in 1968 with an annual production capacity of 30,000 tons of ferrochromium. Periodic upgrades, including the addition of a new pelletizing plant in 1989, boosted production capacity to its current annual level of 230,000 tons of high-carbon ferrochromium graded at 52% chromium and 6% to 8% carbon. Commercial stainless steel production began in 1976 with a planned annual production capacity of 50,000 tons of stainless steel. Outokumpu supplies about 40% of its ferrochromium needs for stainless steel production as hot metal. It started construction of a new ferrochromium converter that will permit it to supply 90% of its ferrochromium needs as hot metal which, in turn, will increase its stainless steel melt shop capacity from 400,000 to 500,000 tons when the project is completed in 1996. For 1993 Outokumpu reported chromite ore mined at 1.0 million tons, ferrochromium production at 218,000 tons and raw stainless steel production at 371,000 tons. For 1994 Outokumpu reported chromite ore mined at 1.1 million tons, ferrochromium production at 229,000 tons, and stainless steel production at 426,000 tons.

Germany.—Bayer AG's chromium chemicals plant at Leverkusen has been supplying chemicals for its recently closed plants in South Africa and Spain.

***India.*—National.—**The Indian govern-ment opened its chromite mining industry to private and foreign investment of up to 50% ownership.

Chromite.—Indian Bureau of Mines (IBM) reported chromite ore total geological resources of 182 million tons, 96% of which was in Cuttack district of Orissa State. Reserves were 88.351 million tons (98% in Orissa, 1% in Karnataka, and the remainder in Andhra Pradesh, Bihar, Maharashtra, Manipur, and Tamil Nadu). The major chromite mining companies were; Tata Iron and Steel Co. Ltd., Orissa Mining Corp. Ltd., Ferro Alloys Corp. Ltd, and Mysore Minerals Ltd. Chromite production was 1,045,513 tons in 1989–90 (average Cr_2O_3 content of 44.4%), and 939,597 tons 1990–91 (average Cr_2O_3 content of 44.5%), 1,087,204 in 1991–92, and 1,064,190 tons in 1992–93. India reported chromite ore domestic consumption of 427,500 tons in 1988, 476,600 tons in 1989–90, and 486,300 in 1990–91. The distribution of production in 1990–91 was 87% to chromium ferroalloy production, 7% to refractory production, and 6% to chemical production.

Orissa Mining Corp. started operation of and shipments of chromite ore from its new beneficiation plant at its Kaliapani Mine, Cuttack District, Orissa State. The plant was planned to consume about 100,000 tons per year of chromite ore graded at 50% Cr_2O_3 to produce about 84,000 tons per year of chromite ore concentrate (62,000 tons of sand and 22,000 tons of fine concentrate) graded at from 54% to 55% Cr_2O_3. SiO_2 was to be kept at under 1%.

Federation of Indian Minerals Industry and Indian Metals and Ferro Alloys Limited reported India's chromite ore reserves to be in the range of 182 to 186 million tons distributed among grades as follows: 40 million tons proven, 80 million tons possible, and 60 million tons probable. The difference between IBM reserves and privately reported reserves results from the difference in definition. IBM surveys to 50 meters depth whereas mining companies survey to greater depth.

Indian Metals and Ferro Alloys sought to increase its chromite ore leases in order to avoid the necessity of buying ore from its competitors. Holdings were distributed as follows: Tata Iron and Steel, 69%; Orissa Mining, 21%; and Ferro Alloys, 4%. Indian Metals and Ferro Alloys and other companies held the remainder. The Indian court approved the extension of Tata's chromite leases and recommended a feasibility study on sharing part of Tata's lease with another mining company.

Ferrochromium.—IBM reported ferro-chromium (i.e., ferrochrome plus charge chrome) production of 137,301 tons in 1989–90; 149,966 tons in 1990–91; and 192,674 tons in 1991–92. Reported 1990–91 ferrochrome consumption of 21,750 tons, 90% of which went into alloy steel. The major ferrochromium producers included: Deepak Ferro-Alloys Ltd., Ferro Alloys Corp. Ltd., Indian Metals and Ferro Alloys, Jindal Ferro-Alloys Ltd., Tata Iron and Steel, and Ispat Alloys Ltd. started construction of a 7.5-megavolt-ampere furnace for ferrochromium production. The furnace was planned to have an annual ferrochromium production capacity of 15,000 tons and to start production in 1995.

Chemicals.—Narco Chemicals Ltd. started production of sodium dichromate at the Fatuha Industrial Area of Bihar. Annual production capacity is 875 tons of sodium dichromate,

3,500 tons of basic chromium sulfate, and 2,100 tons of sodium sulfate. The chemicals were to supply the leather tanning industry.

Iran.—Faryab Mining and Chrome Smelting Co. started ferrochromium production from a 12.5-megavolt-ampere furnace for domestic consumption and export. Export was planned to start in 1995. Plant construction started in 1992. Annual ferrochromium production capacity was estimated at about 7,000 tons.

Italy.—The Bettoni Group were ordered by a Brescia Court to cease activity after Bettoni failed to meet debt payments. Included in the group is Fucinati, a ferrochromium producer with 22,000 to 25,000 tons per year production capacity. Fucinati stopped furnace production in 1993 but continued to sell ferrochromium recovered from slag produced as part of a joint venture with Aktubinsk (Kazakhstan).

Japan.—Japan planned to reduce its current ferrochromium import duty of 7.2% by one-third in accordance with the Uruguay Round GATT agreement. Japan's planned ferrochromium import duty reduction schedule is as follows: 1995, 7.2%; 1996, 6.9%; 1997, 6.4%; 1998, 5.8%; and 1999, 5.3%.

Japan operated a two-part stockpiling program, Government and private. Japan's long-term goal was to acquire a stockpile of chromium materials adequate to serve the needs of Japanese industry for 60 days. Japan planned to have the Government finance and stockpile 70% of the material; the private sector, the remaining 30%. They also planned to reach the 60 day-supply target in 1995. Metal Mining Agency of Japan, under the supervision of the Ministry of International Trade and Industry, operated the government stockpile, while Japan Rare Metals Stockpiling Association operated the private stockpile. Japan appropriated money to continue stockpile purchases through fiscal year 1995 (April 1995--March 1996).

Japan imported 664,545 tons of chromite ore, 608,273 tons of ferrochromium, 2,026 tons of chromium metal, and 194,956 tons of stainless steel scrap. Japan's ferroalloy industry produced about 215,924 tons of ferrochromium, a decline of 4% compared with that of 1993. (Japan's annual ferrochromium production has ranged about from 216,000 tons to 360,000 tons in the 1980-93 time period with the lower limit set in 1994.) Japan reported hot rolled stainless steel production of 2,863,878 tons in 1994, an increase of 7% compared with that of 1993. Japan exported 1,168 tons of ferrochromium and 1,038,226 tons of stainless steel. Chromium metal imports showed substantial increases in recent years owing to the closure of Japan's chromium metal producer: 38% increase in 1994, 48% in 1993, 25% in 1992, and 44% in 1991. Japan has become the World's second largest importer of chromium metal. Ferrochromium imports represented 74% of market share (up 3% over 1993) while stainless steel exports represented 36% of production. Japan's ferrochromium industry loss of market share in 1994 was attributed to the high value of the yen compared with the U.S. dollar. Based on chromite ore, ferrochromium, and chromium metal trade, chromium apparent consumption in Japan was about 536,000 tons-contained chromium in 1994.

Chromite in the Tari-Misaka ultramafic complex was studied. The complex hosted the Wakamatsu Mine and the Hirose Mine. Petrological and geochemical data were found to support current models of chromite origin.[5]

Kawasaki Steel started production of stainless steel using a new process. Kawasaki purchased chromite ore for production of prereduced chromite briquetes at its Mizushima plant and ferrochromium for stainless steel production at its Chiba plant. Kawasaki operated two, 160-ton converters. Partially reduced chromite pellets, chromite ore, and ferrochromium were introduced in the first converter. The stainless steel was then decarburized in the second converter. The process was expected to consume about 120,000 tons of chromite ore plus 60,000 tons of ferrochromium to produce about 230,000 tons of stainless steel annually.

Japan Metals and Chemicals' Oguni Works closed its ferrochromiumsilicon furnace electing to use imported ferrochromiumsilicon instead for its low-carbon ferrochromium production.

Kazakhstan.—**National.**—Chromium related activity centered around reorganization of the industry as a result of national economic and political reorganization. The Kazakhstan chromium industry moved from state control of the chromite ore mining and two ferrochromium plants in 1990 to semi-independent operations in 1991. As a result of that change and the subsequent entrance of Kazakhstani chromium producers into the world market, Kazakhstan is reorganizing its industry. The government organized the chromium industry into holding companies with Donskoy and Aktubinsk in one company (Kramds) and Yermakovsky in another in 1994. Donskoy left Kramds which was subsequently dissolved. Kazakhstan planned to privatize the mining and ferrochromium industries to bring in money necessary to maintain and develop those industries. Production reportedly was low owing to poor maintenance resulting from inadequate money resources.

Chromite Ore.—The mineralogy, petrology, and geochemistry of the podiform chromite deposits of the Kempirsai massif, southern Urals, were reported. The Kempirsai massif hosts the worlds largest podiform chromite deposits. Mine production from the area is about 4 million tons per year and reserves exceed 300 million tons.

Donskoy Ore Dressing Complex mines and beneficiates chromite ore with an annual production capacity of 3.5 million tons.

Ferrochromium.—Aktubinsk Ferroalloy Plant produced ferrochromium from chromite ore from Donskoy Mining Complex.

Yermakovsky Ferroalloy Plant produced ferrochromium from chromite ore from Donskoy Mining Complex. Yermak produced about 230,000 tons of ferrochromium in 1993. Yermak planned to convert furnaces used to produce other ferroalloy to ferrochromium ultimately reaching an annual ferrochromium production capacity of 700,000 tons.

Madagascar.—Kraomita Malagasy mined chromite ore for export in Madagascar. A hurricane in March caused transportation infrastructure damage sufficient to stop exports until November. Kraomita transports its ore by truck to rail a distance of 90 kilometers, then by rail to Toamasina (formerly Tamatave) port a distance of 370 kilometers. Hurricane damage was repaired by August. However, transportation was limited to essential goods until November. Owing to hurricane damage, limited transportation, and limited oil supply, chromite ore production was reduced to about 85,000 tons in 1994 from the 144,500 tons produced in 1993.

Oman.—Oman explored and geologically mapped the country. Already identified are over 2 million tons of chromite ore reserves being mined by Oman Chromite Co.

Pakistan.—Chromite ore production at Muslimbagh mines based in Baluchistan was reported to be about 5,000 tons per year from 20 to 30 open pits. Metallurgical grade chromite was exported to China while chemical grade was consumed domestically.

Philippines.—**National.**—National Power Corp., the national electrical energy supplier on Mindanao Island, reduced power rates from 1.32 peso per kilowatt-hour to 1.05 peso per kilowatt-hour as a result of abundant rainfall and recovering water levels at Lake Lanao.

Chromite Ore.—Chromite ore production is centered on Luzon Island where Benguet Corp. mines refractory grade chromite from the Coto Mine.

Ferrochromium.—Integrated Chrome Corp. started ferrochromium production in May after having been idle since March 1993. Inchrome started production from its 20 megavolt-ampere furnace at the rate of 2,250 tons of ferrochromium per month. Inchrome suspended

production in mid-September. Metro Alloys planned to restart its three furnaces of which one produces 60% to 65% chromium, high-carbon ferrochromium and a second produces 50% to 55% chromium, high-carbon ferrochromium. Ferrochrome Philippines restarted ferrochromium production in April, after having been idle since December 1993, and idled its furnaces again in July.

***Russia.*—Chromite Ore.—**Russian Federation chromite ore reserves were reported at 648 million metric tons, of which the most promising deposit was the Aganozersky Field in Karelia Autonomous Region with reserves of 200 million tons and the Rai-Izsky deposits in the Arctic Urals with reserves of 30.2 million tons.

Chromite ore production was reported to have been 122,200 tons in 1992 and 120,800 tons in 1993. Ferrochromium production was reported to have been 661,700 tons in 1992 and 623,900 tons in 1993. Chromium metal production was reported to have been 8,500 tons in 1992 and 4,200 tons in 1993. Russia exported 172,270 tons of ferrochromium in 1993.

Ferrochromium.—Chelyabinsk Electrometallurgical Works had 32 ferroalloy furnaces ranging in electrical capacity from 3.5-megavolt-amperes to 33-megavolt-amperes. They reported production between 1985–91 to have been about 250,000 tons of chromium ferroalloys per year distributed among low-carbon ferrochromium, foundry grade, and 48% ferrochromiumsilicon.

Serov Ferroalloy Works had 17 ferroalloy furnaces ranging in electrical capacity from 5 megavolt-amperes to 16.5-megavolt-amperes. They reported annual ferroalloy production between 1981–91 to have been about 300,000 tons of chromium ferroalloys per year distributed among low-, medium-, and high-carbon, and foundry ferrochromium and 48%, 33%, and 20% ferrochromiumsilicon. Serov reported production in 1993 of 133,000 tons of high-carbon ferrochromium, 117,000 tons of low- and medium-carbon ferrochromium, and 85,000 tons of ferrochromiumsilicon. Serov planned to construct a briquetting plant to process its chromite ore supply from Kazakhstan, which had been increasingly composed of fines. Serov received about 5% of its chromite ore from Saranovskaya Mine; the remainder was imported from Kazakhstan. Shortage of chromite ore supply in 1994 lead Serov to abandon the briquetting strategy in favor of developing domestic resources.

Klyuchev Ferroalloy Works had seven ferroalloy furnaces. They reported annual ferroalloy production between 1981–91 to have been about 3,500 tons of chromium ferroalloys per year distributed among low-carbon and 40% ferrochromiumsilicon.

Chromium Metal.—Klyuchev Ferroalloy Works from 1985–91 reportedly produced between 12,000 and 16,000 tons of chromium metal per year. Chromium metal production in Russia has declined substantially since 1985 leaving considerable idle capacity.

***South Africa, Republic of.*—**South African economic policy is one of vertical integration of industries that are based on its domestic mineral assets. To this end, the chromium industry of South Africa has moved from being a major world supplier of chromite ore to being the major supplier of both chromite ore and ferrochromium to Western markets. Further vertical integration will result from Columbus' and ISCOR's planned increase in stainless steel production. South Africa planned to increase stainless steel annual production capacity from the current 140,000 tons to 177,000 tons in 1995, 307,000 tons in 1996, and in excess of 1.1 million tons in 2000, most of which was planned for export. This added capacity would account for about one-half of world stainless steel demand growth over the same time period if historical performance is realized over that time period. Rising transportation cost also encouraged local resource processing.

South Africa reported its chromite ore reserve base in 1993 at 3,200 million tons. South Africa reported declining chromite ore production in 1993 of 2,827,000 tons, only 55% of peak production of 5,100,000 tons in 1991. Preliminary production reports for 1994 of 3,590,000 tons shows a significant recovery in 1994. Chromium ferroalloy production in 1993 was reported at 833,600 tons, down from the 1991 peak of 1,149,200 tons but better than 1992 production of 770,600 tons. Preliminary ferrochromium production data for 1994 of 1,104,000 tons shows further recovery in 1994. Reduced chromite ore and ferrochromium production while world stainless steel production remained strong was attributed to increased availability of chromite ore, ferrochromium, and stainless steel scrap from the former Soviet Union and of ferrochromium from China.

Chromite Ore.—Hernic Mining (Pty.) Ltd. expanded its mineral property. Hernic reported it reserves at 23 million tons graded at 39% to 40% Cr_2O_3. Hernic studied the feasibility of setting up a ferrochromium plant. Lebowa Development Corp. negotiated a plan with the National Union of Mineworkers to reopen the Dilokong Mine in 1995. Dilokong has been idle for 2 years. Samancor Ltd., South Africa's largest chromite mining company, reported an annual production capacity of 2.62 million tons from six locations.

Ferrochromium.—Samancor reported annual ferrochromium production capacity of 973,000 tons from five locations. Samancor reported that it planned to commission a slag recovery facility at its Ferrometals plant in 1995 and that it would study the feasibility of such a plant at its Tubatse and Middelburg plants. Upon completion, ferrochromium recovery from slag processing was expected to increase annual ferrochromium production capacity by 50,000 tons at Ferrometals and by 18,000 tons at Tubatse. Samancor conducted trial transfers of hot ferrochromium from the Middelburg ferrochromium plant to Columbus stainless steel plant in anticipation of expanded stainless production at Columbus. Samancor continued developmental operation of the Chrome Direct Reduction (CDR) process kiln at Middelburg to improve metalization and kiln refractory life. A melting furnace to accept the kiln output has yet to be designed and constructed. Upon implementation, the CDR process was anticipated to add 400,000 tons to Middelburg's annual ferrochromium production capacity. Samancor and Showa Denko (Japan) planned a joint venture wherein Showa Denko would transfer low-carbon ferrochromium production technology to Samancor which would then produce that material at its Middelburg plant for sale in Japan and elsewhere.

Chrome Corp. Technology operated three electric furnaces (annual production capacity of 180,000 tons of ferrochromium), one chromium recovery process (annual production capacity of 20,000 tons of ferrochromium), and one pelletizing plant (annual capacity of 18,000 tons of chromite pellets) in 1994 at its Rustenburg plant. Chrome Corp. Technology started installation of a fourth electric furnace. Upon completion in 1995, Chrome Corp. Technology will have an annual production capacity of 260,000 tons of ferrochromium.

Stainless Steel.—Columbus Joint Venture (CJV) was organized and scheduled for formal recognition as a new company in January 1993. CJV is equally co-owned by Highveld Steel and Vanadium Ltd., Samancor Ltd., and Industrial Development Corp. (IDC). (Samancor Ltd. is co-owned by Gencor and Anglo-American Corp. Highveld Steel is co-owned by De Beers and Anglo-American Corp. IDC is state owned.) CJV constructed new production facilities to increase its current annual production capacity of 120,000 tons to 500,000 tons in 1996. ISCOR studied the feasibility of starting stainless steel production at its Pretoria steel plant.

***Switzerland.*—**Switzerland planned to sell chromium materials from its national strategic materials stockpile.

***Taiwan.*—**Taiwan planned to expand its

stainless steel production capacity.

Turkey.—Etibank, a state-owned company, is Turkey's major chromite ore producer and only ferrochromium producer. The other major chromite ore producers include Hayri Ögelman Madencilik and Bilfer Madencilik AŞ. Etibank operated a low-carbon ferrochromium smelter at Antalya and a high-carbon ferrochromium plant at Elazığ. Chromite ore exports have declined in value from 1991-93 by over 50%, at which level the chromite mining industry operated in 1994. Chromite ore is one of Turkey's major primary mineral export income sources. Turkish chromite ore exports were affected by the change in status of the former U.S.S.R. previously described. In order to stimulate chromite ore production, Etibank planned to lease 32 chromite mines for 4 years.

United Arab Emirates.—The Department of Industry and Economy (Al Fujayrah Emirate) and Derwent Mining (Ireland) started a joint venture to exploit chromite deposits in Al Fujayrah. Derwent Mining Co. started production in 1993 producing lumpy chromite ore graded at 46% to 48% Cr_2O_3 and exported through Al Fujayrah. About 200,000 tons of chromite ore was found grading at 48% Cr_2O_3 with chromium-to-iron ratio of 3:1. Annual mine production capacity was 20,000 to 30,000 tons.

Venezuela.—Venezuela reported identifying chromite mineralization in Falcon and Aragua States. Venezuela reported 10,000 tons of chromite ore graded at 40% Cr_2O_3 in Falcon State and 38 million tons of chromite ore graded at 2.73% Cr_2O_3 in Aragua State.

Zimbabwe.—Zimbabwe reported chromite ore production of 514,000 tons in 1994, up from 252,000 tons in 1993. Zimbabwe reported 1994 ferrochromium production of 182,000 tons (153,000 tons of high-carbon ferrochromium and 29,000 tons of low-carbon ferrochromium). Zimbabwe also produced 36,000 tons of ferro-chromiumsilicon.

Two ferrochromium producers operated in Zimbabwe, Zimbabwe Mining and Smelting and Zimbabwe Alloys. Union Carbide (United States) sold its shares in Zimbabwe Mining and Smelting to a management holding company. It produces high-carbon ferrochromium at Kwekwe with an annual capacity of about 178,000 tons from six electric furnaces. Zimbabwe Alloys is a subsidiary of Anglo American (South Africa). It produces low-carbon ferrochromium with an annual capacity of about 34,000 tons and ferrochromium-silicon at Gweru. Zimbabwe Alloys started construction of a plant to recover chromium from slag (South African process), which was planned to start production in 1995. Zimbabwe Alloys operated a 17.5 megavolt-ampere furnace with an annual ferrochromiumsilicon production capacity of 15,000 tons.

Current Research and Technology

Mineral Processing and Industrial Applications.—The U.S. Geological Survey (USGS) studies the mineral potential of the United States. The USGS reported the chromite potential of the Anchorage Quadrangle, South-Central Alaska, as part of its Alaska mineral resources assessment program. The report identified the Eklutna and Wolverine complexes as containing podiform chromite deposits and reported previous studies of those deposits.[6] A statistical method was developed for estimating undiscovered chromite deposits by characterizing the number of chromite deposits in a well explored permissive area. Based on chromite deposits in Oregon and California, it was found that the relationship between the number of exposed podiform chromite deposits (N) and the area of host ultramafic rock (A) can be represented by the following: $\log_{10}(N)=-0.194+0.577\log_{10}(A)$.[7]

The United Nations (UN) reported on its minerals exploration program. The UN identified nine chromite exploration projects in seven countries.[8]

USBM research provides fundamental scientific and technical information essential for advancing mineral science, processing technology, and conserving and developing domestic mineral resources. This research is conducted in support of the Strategic and Critical Materials Stock Piling Act of 1946 as amended, the Defense Production Act of 1950 as amended, the Mining and Minerals Policy Act of 1970, and the National Materials and Minerals Policy, Research and Development Act of 1980. The USBM studied chromium availability, stainless steel, and chromium material flow and recycling. The USBM analyzed the availability of chromium as chromite products (ore for the chemical, foundry, metallurgical, or refractory industry) or chromium ferroalloys. A total of 873.5 million tons of in-situ chromite ore containing 202.5 million tons of chromium in 10 market economy countries was analyzed. A world network flow model was constructed to analyze world chromium supply and demand interactions.[9] The USBM studied the oxidation of type 304 stainless steel during annealing under varying ambient conditions. A Cr_2O_3 layer formed in the presence of free oxygen, while a chromium-iron spinel layer formed under oxygen-free conditions.[10] A chromium commodity flow model was developed that identifies significant losses. In 1989, the United States consumed 451,769 tons of chromium, including 99,221 tons of chromium from recycling and lost 345,347 tons of chromium to processing losses, manufacturing losses, manufacturing-downgraded scrap, prompt and obsolete scrap export, recovery losses, and recycling losses. Recovery losses, the single-largest loss accounting for nearly one-half of losses, represented chromium contained in obsolete materials never collected for recycling.[11]

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. Recent Mintek research has included chromite beneficiation, agglomeration, smelting, chromium recovery from slag, and stainless steel alloying. Mintek reported development of a novel jigging process that permits efficient recovery of ferrochromium from slag and a plasma process for low-carbon ferrochromium production that permits use of fine feed materials and better energy recovery. Mintek also studied ion-exchange processes for the removal of chromium from water.[12]

Environmental.—Environmental concerns about chromium have resulted in a wide variety of studies to determine 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. A broad review of many environmental factors and the role of chromium, among other metals, in the environment was published.

The EPA reported on chromium emissions from electroplating operations and chromium recovery from electroplating rinse waters.[13]

The International Chromium Development Association published industry guidelines on health, safety, and environment. The guidelines take account of extensive international changes and developments in legislation and regulation of chromium materials and is intended to help companies implement appropriate workplace practices and procedures for environmental protection.[14]

Chromium leaching behavior in soil derived from the kiln roasting and leaching of chromite ore was reported. It was found that (1) leaching was highly sensitive to pH and that the most chromium leached out at soil pH between 4 and 12 and (2) the presence of organic matter in the soil reduced the amount of chromium leached out.[15]

Outlook

The ferrochromium industry developed in

close proximity to stainless steel industry. Since then, ferrochromium production capacity has moved to chromite producing areas. Further vertical integration of the chromium industry is occurring as Finland and South Africa increase its stainless steel production capacities. Two industry process trends were evolving, chromium recovery from slag in the ferrochromium industry and supply of still melted ferrochromium to stainless steel production. Both of these trends improve chromium recovery efficiency.

The outlook for chromium consumption in the United States and internationally is the same as that for stainless steel. Stainless steel is the major end use for chromium worldwide. Thus, stainless steel industry performance determines chromium industry demand worldwide.

The trend to supply chromium in the form of ferrochromium by chromite mining countries is expected to continue. With new, efficient ferrochromium production facilities and excess capacity in chromite-producing countries, both production and capacity are expected to diminish in traditional ferrochromium-producing countries, except where domestic industries are protected by quotas and tariffs. Further upward integration of the chromium industry is expected as chromite-producing countries expand ferrochromium or stainless steel production capacity.

In the 1989–90 time period, ferrochromium demand exceeded supply causing prices to increase appreciably. The industry used its profits from the price increase to expand capacity by about 15% in the 1991–92 time period. Capacity expansions took place primarily in chromite producing countries with South Africa as the major benefactor of added capacity. With a growth rate in stainless steel consumption of about 3% per year, it was estimated that about 5 years of average stainless steel demand growth to bring the ferrochromium supply-stainless steel demand back into equilibrium. The dissolution of the former U.S.S.R. in 1991 and subsequent reorganization resulted in declining chromium demand in the former U.S.S.R. without loss of chromium-material production capacity. As a result, significant quantities of chromium raw materials including chromite ore, ferrochromium, chromium chemicals, and chromium containing scrap, entered Western markets from the former U.S.S.R. The integration of the former Eastern Block with the West exacerbated the already excess production capacity in the West. During this same time period, China shifted ferroalloy production capacity to ferrochromium production.

In 1992 and 1993 significant rationalizations took place in Western chromite mining and ferrochromium industries. Not all added capacity from the 1991–92 time period could be brought into production or, if brought into production, could be fully utilized. The South African chromite ore and ferrochromium industry operated at 50% to 60% of design capacity to reduce supply in excess of world demand. Several ferrochromium producers idled furnaces or converted furnaces to ferromanganese production. The ferrochromium industry in Japan continued to be rationalized. As the Japanese ferrochromium industry continues rationalizing, the Japanese chromium industry shows greater interest in buying into the South African ferrochromium industry.

The world chromium industry in 1994 operated with supply capacity in excess of demand for most of the year. As 1994 drew to a close, increased demand for chromium ferroalloys by the Western world stainless steel industry, reduced supply owing to reduced chromite ore production in Kazakhstan, and low capacity utilization in South Africa and elsewhere resulted in chromium demand exceeding supply, and ferrochromium price started increasing. By yearend, ferrochromium demand exceeded supply. Furnaces were planned to restart ferrochromium production. Even before all of existing ferrochromium production capacity could be brought back into production, some new furnaces were planned in South Africa and chromium recovery from slag processes were planned or implemented.

It is anticipated that industrial renovation and unfulfilled consumer demand in the former U.S.S.R. could stimulate recovery in those countries and add to world demand for chromium-containing products.

A review of the world minerals industry by mineral, country, and mining company was reported. The composite world rank of chromium was found to be 10th out of 36 minerals indicating chromite to be the 10th most globally important strategic investment mineral commodity. The composite world rank is an indexed composite of five factors: output by value, population and gross domestic product, resource demand, mineral reserve base, and country investment risk.[16]

Stainless Steel.—World stainless steel production was steady in 1993–94. Former Soviet Union stainless steel production has declined since political dissolution in 1991. Western world stainless steel production has been growing since 1970 with an increased rate in the 1983–94 time period over that of the 1970–83 time period. Western world stainless steel production increased by 4% in 1993 and by 12% in 1994. In 1994, Western world stainless steel production grew in each producer sector, Europe, Japan, and the United States. European production grew about 11%, followed by Japan with a growth of 7% and the United States with a growth of 3%. Stainless steel production growth over the past two decades permitted the entry of nontraditional producers in the past decade. Other Western world stainless steel producers' capacity now rivals that of the major producers and is projected to make substantial growth in the next 2 years.

Further growth in stainless steel production was anticipated for 1995 and years immediately following. Long-term growth, strong short-term growth, near capacity utilization, and increased profitability caused stainless steel producers to plan Western world capacity expansions in 1995–96. About 800,000 tons of production capacity is expected to be added to the current U.S. capacity of 2 million tons; about 900,000 tons to current European capacity of 6 million tons; about 1.5 million tons to current other Western world capacity of 2 million tons; no additions to current Japanese capacity of 3.5 million tons.

From 1989–94, world production of chromite ore and of ferrochromium declined while world production of stainless steel, the major end use for chromium, has been steady. This trend resulted from declining ferrochromium utilization rate, which, in turn, resulted from increased use of scrap and the drawndown of ferrochromium stocks to supply stainless steel production. The trend is limited by stock supply and the supply growth of stainless steel scrap. The production of chromite ore, ferrochromium, and stainless steel all showed an upturn in 1994.

Projected stainless steel production growth is expected to reverse the decline in world chromite ore production. The projected addition of 3.2 million tons of stainless steel production capacity (current world capacity of 16 million tons), when utilized according to 1994 industry performance, should increase demand for ferrochromium by about 900,000 tons (25% of 1994 production) and demand for chromite ore by 2.3 million tons (24% of 1994 production).

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

Chromium Chemicals.—Sodium bichromate demand was about 132,000 tons in 1994.

Its U.S. production has been growing at about 1% per year and was expected to continue at that rate. Sodium bichromate was used to make chromic acid (64%), leather tanning (12%), chromic oxide (10%), and other end uses including wood preservatives, drilling mud additives, metal treatments, and textiles (8%). Chromic acid demand in 1994 was about 53,000 tons. Its U.S. production has been growing at about 1% per year and was expected to continue to do so. Chromic acid was used for wood preservatives (68%), metal finishing (22%), and other uses (10%) including water treatment, magnetic particles, and catalysts. Demand for wood preservatives and magnetic particles for the recording industry has been growing. World demand for chromium chemicals has been declining resulting in facility closure and capacity rationalization. Closures and rationalizations were attributed to reduced demand owing more stringent environmental regulations, general overcapacity, and collapse of the Russian economy.

A review of lead chromate pigments found that owing to restrictions on lead, use of lead chromate pigments is declining and may be nil within the next 13 years. Chrome yellow is a lead chromate pigment. The major use of chrome yellow is in coatings and plastics. As a coating, chrome yellow is used to color paint for highway center stripes. In plastics, chrome yellow is used to tint engineering resins.

EPA regulations limiting chromium releases have encouraged recycling of chromium chemicals and the use of substitutes to reduce releases. As a result, demand is expected to be reduced for many end uses.

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World Stainless Steel Statistics.

TABLE 1
SALIENT CHROMIUM STATISTICS 1/

(Thousand metric tons, contained chromium)

	1990	1991	1992	1993	1994
WORLD PRODUCTION					
Chromite ore (mine) 2/	3,960 r/	4,020 r/	3,300 r/	2,800 r/	2,890 e/
Ferrochromium (smelter) 3/	2,150 r/	2,210 r/	2,100 r/	1,870 r/	2,000 e/
Stainless steel 4/	2,230 r/	2,260	2,170	2,100 r/	2,210 e/
U.S. SUPPLY					
Components of U.S. supply:					
Domestic mines	--	--	--	--	--
Secondary	101 r/	96 r/	102 r/	92 r/	99
Imports:					
Chromite ore	92	65	68	84	60
Chromium ferroalloy	244	234	247	233	198
Chromium metal	7	6	5	6	7
Chromium chemicals	4	5	4	6	9
Stocks, Jan. 1:					
Government	1,260 r/	1,270 r/	1,250 r/	1,280 r/	1,210
Industry	139	126 r/	118	118	103
Total U.S. supply	1,840 r/	1,800 r/	1,800 r/	1,820 r/	1,690
Distribution of U.S. supply:					
Exports:					
Chromite ore	2	3	2	3	14
Chromium ferroalloy and metal	6 r/	7 r/	7 r/	9	8
Chromium chemicals	9 r/	9	9 r/	8 r/	12
Stocks, Dec. 31:					
Government	1,270 r/	1,250 r/	1,280 r/	1,210 r/	1,170
Industry	126	118	118	104	101
Total U.S. distribution	1,410 r/	1,390 r/	1,420 r/	1,340 r/	1,300
Apparent industry demand	432 r/	413 r/	378 r/	484 r/	390

e/ Estimated. r/ Revised.

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to 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%.

TABLE 2
HISTORICAL PERFORMANCE OF THE NATIONAL DEFENSE STOCKPILE
CHROMITE ORE TO FERROCHROMIUM CONVERSION PROGRAM 1/

Contract year	Ore converted (metric tons)	High- carbon ferrochromium produced (metric tons)		Cost (millions)	
		Gross	Content		
1993 r/	147,000	49,800	34,100	$30.9	
1994	84,100 r/	30,800 r/	21,100	19.6	r/

r/ Revised.

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits. Program completed in August 1994.

Source: Defense Logistics Agency.

TABLE 3
HISTORICAL PERFORMANCE OF THE NATIONAL DEFENSE STOCKPILE
LOW-CARBON FERROCHROMIUM TO CHROMIUM METAL CONVERSION PROGRAM 1/

Time period	Low-carbon ferrochromium 2/ (metric tons)	Chromium metal (metric tons)	Cost (millions)
October 1992 - September 1993	2,890	616 r/	$5.6 r/
October 1993 - September 1994	(3/)	835	7.5

r/ Revised.
1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits. Program completed in August 1994.
2/ Nonspecification grade.
3/ Stocks from the previous period were used to produce chromium metal.

Source: Defense Logistics Agency.

TABLE 4
MANUFACTURING INDUSTRY CHROMIUM 1/ RELEASE TO THE ENVIRONMENT
AND TRANSFER BY MODE AND BY YEAR 2/

Mode	1991	1992
	Metric tons, contained chromium	
Releases:		
To air	442	448
To water	160	133
To underground	16	15
To land:		
Fill	2,080	1,640
Treatment	41	111
Impoundment	9,500	9,010
Other	144	176
Total release	12,400	11,500
Transfers:		
To POTW	425	428
To off-site location:		
Disposal	7,120	6,460
Recycling	30,200	43,700
Treatment	1,720	1,720
Other	199	295
Total transfer	39,700	52,600
Total releases plus transfers	52,100	64,100
	Percent	
Releases: 3/		
To air	4	4
To water	1	1
To underground	(4/)	(4/)
To land:		
Fill	17	14
Treatment	(4/)	1
Impoundment	77	78
Other	1	22
Transfers: 5/		
To POTW	1	1
To off-site location:		
Disposal	18	12
Recycling	76	83
Treatment	4	3
Other	1	1
Totals: 6/		
Total release	24	18
Total transfer	76	82

1/ Chromium contained in EPA categories chromium and chromium compounds.
2/ Data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
3/ Releases as percent of total releases.
4/ Less than 1/2 unit.
5/ Transfers as percent of total transfers.
6/ Totals as percent of total releases plus transfers.

NOTE: Air included point and non-point (i.e. stack and fugitive) sources. POTW is publicly owned treatment works.

Source: Environmental Protection Agency, Toxic Release Inventory (May 1994).

TABLE 5
CHROMIUM 1/ RELEASED TO THE ENVIRONMENT AND TRANSFERRED BY INDUSTRY 2/

(Metric tons, contained chromium)

SIC 3/	Industry	1991	1992
20	Food products	85	41
21	Tobacco products	(4/)	(4/)
22	Textile mill products	38	65
23	Apparel	29	--
24	Lumber and wood products	91	64
25	Furniture	70	585
26	Paper and allied products	149	112
27	Printing and publishing	4	5
28	Chemical and allied products	9,960	9,460
29	Petroleum and coal	299	267
30	Rubber and plastic	183	128
31	Leather and leather products	887	967
32	Stone, clay, glass, and concrete	685	1,180
33	Primary metals	19,800	28,400
34	Fabricated metals	6,350	8,160
35	Machinery and computer equipment	7,220	7,920
36	Electrical and electronic equipment	1,070	771
37	Transportation equipment	4,750	5,460
38	Instruments	212	363
39	Miscellaneous manufacturing	58	77
	Other	196	167
	Total	52,100	64,100

1/ Chromium contained in EPA categories chromium and chromium compounds.
2/ Data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
3/ Standard industrial classification code.
4/ Less than 1/2 unit.

Source: Environmental Protection Agency, Toxic Release Inventory (May 1994).

TABLE 6
PRINCIPAL U.S. PRODUCERS OF CHROMIUM PRODUCTS IN 1994, BY INDUSTRY

Industry and company	Plant
Metallurgical:	
Elkem AS, Elkem Metals Co.	Marietta, OH and Alloy, WV.
Macalloy Corp.	Charleston, SC.
Refractory:	
General Refractories Co.	Lehi, UT.
Harbison-Walker Refractories, a division of Dresser Industries Inc.	Hammond, IN.
National Refractories & Mining Corp.	Moss Landing, CA and Columbiana, OH.
North American Refractories Co. Ltd.	Womelsdorf, PA.
Chemical:	
American Chrome & Chemicals Inc.	Corpus Christi, TX.
Occidental Chemicals Corp.	Castle Hayne, NC.

TABLE 7
PRODUCTION, SHIPMENTS, AND STOCKS OF CHROMIUM FERROALLOYS AND METAL, AND OTHER CHROMIUM MATERIALS IN THE UNITED STATES 1/

(Metric tons)

	Net production		Net	Producer
Year	Gross weight	Chromium content	shipments	stocks, Dec. 31
1993	63,000	44,500	61,200	5,610
1994	67,400	45,800	63,900	8,070

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits.

TABLE 8
CONSUMPTION OF CHROMITE AND TENOR OF ORE USED BY PRIMARY CONSUMER GROUPS IN THE UNITED STATES 1/

Year	Chemical and metallurgical industry		Refractory industry		Total	
	Gross weight (metric tons)	Average Cr_2O_3 (percentage)	Gross weight (metric tons)	Average Cr_2O_3 (percentage)	Gross weight (metric tons)	Average Cr_2O_3 (percentage)
1993	314,000	47.8	22,900	39.1	337,000	47.2
1994	302,000	47.8	20,100	40.0	322,000	47.3

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

TABLE 9
U.S. CONSUMPTION OF CHROMIUM FERROALLOYS AND METAL, BY END USE 1/

(Metric tons, gross weight unless noted)

End use	Ferrochromium		Ferro-chromium-silicon	Other	Total
	Low-carbon 2/	High-carbon 3/			
1993:					
Steel:					
Carbon	4,800	7,440	185	50	12,500 r/
Stainless and heat-resisting	8,450	271,000	W	100	279,000
Full-alloy	3,400	22,900	1,190	44	27,500
High-strength, low-alloy and electric	1,810	2,900	6,400	--	11,100
Tool	W	2,910	W	W	2,910
Cast irons	1,030	4,060	W	19	5,110
Superalloys	2,550	3,390	--	3,140	9,080 r/
Welding materials 4/	W	W	W	255 r/	255 r/
Other alloys 5/	1,210	275 r/	1 r/	1,180 r/	2,660 r/
Miscellaneous and unspecified	1,960	447 r/	7,710	398 r/	10,500 r/
Total 6/	25,200 r/	315,000 r/	15,500	5,180 r/ 7/	361,000 r/
Chromium content	16,900 r/	191,000	5,620	4,730 r/	218,000 r/
Stocks, December 31, 1993	3,080 r/	12,300 r/	391	656 r/ 8/	16,400 r/
1994:					
Steel:					
Carbon	4,520	6,950	199	W	11,700
Stainless and heat-resisting	8,180	252,000	14,800	41	275,000
Full-alloy	3,200	23,000	1,370	W	27,600
High-strength, low-alloy and electric	1,820	2,030	7,230	--	11,100
Tool	W	2,980	W	W	2,980
Cast irons	1,050	3,890	W	12	4,950
Superalloys	2,090	4,280	--	3,080	9,450
Welding materials 4/	15	122	--	W	137
Other alloys 5/	731	340	--	1,350	2,420
Miscellaneous and unspecified	1,580	227	985	797	3,590
Total 6/	23,200	296,000	24,600	5,280 9/	349,000
Chromium content	15,700	176,000	8,910	4,690	205,000
Stocks, December 31, 1994	1,960	12,000	527	473 10/	14,900

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."
1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
2/ Low-carbon ferrochromium contains less than 3% carbon.
3/ High-carbon ferrochromium 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 4,060 tons of chromium metal.
8/ Includes 481 tons of chromium metal.
9/ Includes 3,910 tons of chromium metal.
10/ Includes 292 tons of chromium metal.

TABLE 10
U.S. CONSUMER STOCKS OF CHROMITE, CHROMIUM FERROALLOYS, AND METAL, DECEMBER 31 1/

(Metric tons, gross weight)

Industry	1993	1994
Chromite:		
Chemical and metallurgical	259,000	250,000
Refractory	15,500	16,500
Total	275,000	266,000
Chromium ferroalloy and metal:		
Low-carbon ferrochromium	3,080 r/	1,960
High-carbon ferrochromium	12,300 r/	12,000
Ferrochromium-silicon	391	527
Other 2/	656 r/	473
Total	16,400 r/	14,900

r/ Revised.

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

2/ Includes chromium briquets, chromium metal, exothermic chromium additives, and other miscellaneous chromium alloys.

TABLE 11
U.S. GOVERNMENT STOCKPILE YEAREND INVENTORIES AND ANNUAL DISPOSALS FOR CHROMIUM IN 1994

(Metric tons, gross weight)

Material	Inventory 1/	Disposals 2/
Chromite, metallurgical	905,000	187,000
Chromite, chemical	220,000	--
Chromite, refractory	345,000	28,100
High-carbon ferrochromium	740,000	36,000
Low-carbon ferrochromium	283,000	--
Ferrochromium-silicon	52,900	--
Chromium metal, aluminothermic	2,670	--
Chromium metal, electrolytic	5,020	--

1/ Includes specification- and nonspecification-grade material.
2/ Includes material that is intended for sale or trade.

Source: Defense Logistics Agency.

TABLE 12
TIME-VALUE 1/ RELATIONSHIPS FOR CHROMITE ORE

(Average annual value, dollars per metric ton of contained chromium)

Year	Not more than 40% chromic oxide	More than 40% but less than 46% chromic oxide	46% or more chromic oxide	Total, all grades
1993	506	204	190	196
1994	574	219	205	233

1/ Customs value per ton of chromium contained in imported material.

TABLE 13
TIME-VALUE 1/ RELATIONSHIPS FOR FERROCHROMIUM AND CHROMIUM METAL 2/

(Average annual value)

	Ferrochromium (dollars per metric ton of contained chromium)			Chromium metal (dollars per metric ton
Year	Low-carbon 3/	High-carbon 4/	Total, all grades	gross weight)
1993	1,390 r/	679	801 r/	6,140
1994	1,190	638	767	6,030

1/ Customs value per ton of chromium contained in imported material.
2/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits.
3/ Carbon not more than 4%.
4/ More than 4% carbon.

TABLE 14

PRICE QUOTATIONS FOR CHROMIUM MATERIALS AT BEGINNING AND END OF 1994

Material	January	December	Year average
	Dollars per metric ton of product		
Chromite ore:			
South Africa, Republic of	50 - 60	50 - 60	55
Turkey	105 - 110	105 - 110	108
	Cents per pound of chromium		
High-carbon ferrochromium:			
Domestic: 50% to 55% chromium	52	52	52
Imported:			
50% to 55% chromium	35.5 - 38	37.5 - 38	37
60% to 65% chromium	35 - 35.5	37.5 - 38.5	36
Low-carbon:			
Domestic:			
0.05% carbon	95	95	95
0.015% carbon (Simplex)	166	166	166
Imported:			
0.05% carbon	71 - 73	81 - 83	82
0.10% carbon	53 - 55	68 - 72	67
	Cents per pound of product		
Chromium metal (domestic):			
Electrolytic	370.0	370.0	370.0
Elchrome	450.0	450.0	450.0

Source: Platt's Metals Week.

TABLE 15
U.S. EXPORTS OF CHROMIUM MATERIALS, BY TYPE 1/

Type	1993 Gross weight (metric tons)	1993 Value (thousands)	1994 Gross weight (metric tons)	1994 Value (thousands)	Principal destinations, 1994
Chromite ore and concentrate	10,000	$2,140	47,100	$3,550	Norway (73%); Canada (21%); Mexico (4%).
Metal and alloys:					
Chromium metal 2/	472	4,480	446	4,150	Canada (52%); Japan (30%).
Chromium ferroalloys:					
High-carbon ferrochromium 3/	10,100 4/	7,800	6,220 5/	5,260	Canada (61%); Mexico (35%).
Low-carbon ferrochromium 6/	4,390 7/	5,370	5,320 8/	6,450	Canada (58%); Mexico (13%); Netherlands (12%); Germany (8%).
Ferrochromium-silicon	800 9/	759	499 10/	554	Canada (90%); Mexico (8%).
Total ferroalloys	15,300 11/	13,900	12,000 12/	12,300	
Chemicals:					
Chromium oxides:					
Chromium trioxide	5,010	9,350	5,940	11,200	Canada (30%); Japan (15%); Republic of Korea (12%); Mexico (9%); Taiwan (8%); Australia (6%).
Other	2,040	11,500	2,450	14,700	Canada (38%); Netherlands (15%); Republic of Korea (12%); Japan (11%).
Chromium sulfates	31	71	10	45	Mexico (90%); Germany (10%).
Salts of oxometallic or peroxometallic acids:					
Zinc and lead chromate	501	4,300	938	3,150	Canada (97%); Japan (2%).
Sodium dichromate	11,700	7,800	19,600	13,000	Mexico (45%); Thailand (13%); Colombia (7%); Peru (6%).
Potassium dichromate	34	88	45	121	Canada (49%); Brazil (22%); Colombia (15%).
Other chromates, dichromates, and peroxochromates	635	1,840	470	1,750	Australia (46%); Canada (38%); United Kingdom (8%).
Pigments and preparations	2,310	9,400	1,310	6,010	Canada (28%); Israel (10%); Philippines (9%).

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
2/ Articles thereof and waste and scrap.
3/ More than 4% carbon.
4/ Contained 5,990 tons of chromium.
5/ Contained 3,700 tons of chromium.
6/ Not more than 4% carbon.
7/ Contained 2,670 tons of chromium.
8/ Contained 3,280 tons of chromium.
9/ Contained 280 tons of chromium.
10/ Contained 174 tons of chromium.
11/ Contained 8,950 tons of chromium.
12/ Contained 7,150 tons of chromium.

Source: Bureau of the Census.

TABLE 16
U.S. IMPORTS FOR CONSUMPTION OF CHROMITE ORE, BY COUNTRY 1/

	Not more than 40% Cr_2O_3			More than 40% but less than 46% Cr_2O_3			46% or more Cr_2O_3			Total		
	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)	Gross weight (metric tons)	Cr_2O_3 content (metric tons)	Value (thousands)
1993:												
Philippines	6,420	2,130	$737	--	--	--	--	--	--	6,420	2,130	$737
South Africa, Republic of	--	--	--	2,310	1,060	$148	246,000	120,000	$15,600	248,000	121,000	15,800
Total	6,420	2,130	737	2,310	1,060	148	246,000	120,000	15,600	255,000	123,000	16,500
1994:												
Philippines	8,060	2,620	1,250	450	187	84	--	--	--	8,510	2,810	1,340
South Africa, Republic of	19,900	3,650	1,210	18,300	8,410	1,200	155,000	72,300	10,200	193,000	84,400	12,600
Total	27,900	6,270	2,470	18,700	8,600	1,290	155,000	72,300	10,200	201,000	87,200	13,900

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 17
U.S. IMPORTS FOR CONSUMPTION OF FERROCHROMIUM, BY COUNTRY 1/

Country	Low-carbon (not more than 3% carbon)			Medium-carbon (more than 3% carbon but not more than 4% carbon)			High-carbon (more than 4% carbon)			Total (all grades)		
	Gross weight (metric tons)	Chromium content (metric tons)	Value (thou-sands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thou-sands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thou-sands)	Gross weight (metric tons)	Chromium content (metric tons)	Value (thou-sands)
1993:												
Albania	--	--	--	--	--	--	7,180	4,320	$2,960	7,180	4,320	$2,960
China	--	--	--	--	--	--	3,710	2,310	1,830	3,710	2,310	1,830
Croatia	--	--	--	--	--	--	21,300	13,400	8,740	21,300	13,400	8,740
Finland	--	--	--	--	--	--	38,200	20,400	15,400	38,200	20,400	15,400
France	--	--	--	--	--	--	6	4	6	6	4	6
Germany	10,200	7,370	$18,400	--	--	--	210	140	172	10,400	7,510	18,600
India	--	--	--	--	--	--	13,600	7,970	5,640	13,600	7,970	5,640
Japan	288	208	866	--	--	--	124	83	243	412	291	1,110
Kazakhstan	5,350	2,750	3,280	--	--	--	30,400	18,900	11,600	35,700	21,700	14,900
Netherlands	--	--	--	--	--	--	25	17	25	25	17	25
Poland	--	--	--	--	--	--	32	22	20	32	22	20
Russia	22,600	13,200	15,300	--	--	--	16,700	10,900	7,230	39,300	24,100	22,500
South Africa, Republic of	5,220	2,890	3,660	--	--	--	74,800	37,400	25,800	80,000	40,300	29,400
Turkey	5,950	4,180	4,920	--	--	--	84,700	52,300	32,900	90,700	56,400	37,800
Ukraine	4,070	2,770	2,040	3,260	2,260	$1,240	10,800	7,440	3,500	18,100	12,500	6,780
United Kingdom	38	26	51	123	83	84	410	249	277	570	358	412
Zimbabwe	5,730	3,560	4,850	--	--	--	22,100	14,400	12,800	27,800	17,900	17,600
Total	59,400	37,000	53,400	3,380	2,350	1,330	324,000	190,000	129,000	387,000	229,000	184,000
1994:												
Albania	--	--	--	--	--	--	7,690	4,800	3,250	7,690	4,800	3,250
China	3,010	1,970	2,770	--	--	--	370	222	146	3,380	2,190	2,920
Croatia	--	--	--	--	--	--	21,200	13,100	7,820	21,200	13,100	7,820
Estonia	--	--	--	--	--	--	2,000	1,350	804	2,000	1,350	804
Finland	--	--	--	--	--	--	13,800	7,670	5,680	13,800	7,670	5,680
France	60	41	75	--	--	--	3	2	4	63	43	78
Germany	4,420	3,160	9,060	--	--	--	53	36	33	4,470	3,200	9,090
India	--	--	--	--	--	--	7,250	4,460	3,040	7,250	4,460	3,040
Japan	580	400	1,580	--	--	--	86	57	169	666	456	1,750
Kazakhstan	9,100	6,380	5,650	1,800	1,210	613	18,300	11,800	6,970	29,200	19,300	13,200
Macedonia	324	220	269	--	--	--	--	--	--	324	220	269
Mexico	--	--	--	397	281	179	--	--	--	397	281	179
Poland	--	--	--	--	--	--	386	263	243	386	263	243
Russia	30,700	20,800	23,700	--	--	--	25,700	16,700	11,000	56,500	37,500	34,700
Slovakia	2,060	1,450	934	--	--	--	--	--	--	2,060	1,450	934
South Africa, Republic of	10,800	5,940	5,010	2,600	1,310	954	67,200	34,100	22,400	80,600	41,300	28,400
Sweden	--	--	--	--	--	--	120	80	65	120	80	65
Turkey	1,720	1,190	1,520	30	19	21	62,500	38,800	24,000	64,300	40,000	25,500
Ukraine	303	222	451	--	--	--	--	--	--	303	222	451
United Kingdom	17	13	30	--	--	--	198	133	230	215	146	260
Former U.S.S.R.	--	--	--	--	--	--	3,320	2,290	1,060	3,320	2,290	1,060
Zimbabwe	1,310	694	946	--	--	--	18,000	11,500	7,070	19,300	12,200	8,020
Total	64,500	42,500	52,000	4,830	2,820	1,770	248,000	147,000	94,000	317,000	193,000	148,000

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

Source: Bureau of the Census.

TABLE 18
U.S. IMPORTS FOR CONSUMPTION OF CHROMIUM MATERIALS, BY TYPE 1/

Type	1993 Gross weight (metric tons)	1993 Value (thousands)	1994 Gross weight (metric tons)	1994 Value (thousands)	Principal sources, 1994
METALS AND ALLOYS					
Chromium metal:					
Waste and scrap	437	$2,000	366	$1,730	China (93%); Russia (6%).
Other than waste and scrap	5,730	35,900	6,160	37,600	China (30%); France (22%); United Kingdom (18%); Russia (15%).
Ferrochromium-silicon	8,750 2/	6,180	15,100 3/	7,790	Russia (42%); China (27%); Zimbabwe (26%).
CHEMICALS					
Chromium oxides and hydroxides:					
Chromium trioxide	362	1,280	2,540	4,820	Kazakhstan (39%); Germany (36%); China (11%); Japan (7%).
Other	3,090	10,300	5,740	13,900	Kazakhstan (22%); Germany (19%); Canada (18%); Japan (13%); Netherlands (12%).
Sulfates of chromium	162	97	241	166	Turkey (50%); Mexico (22%); Germany (17%).
Salts of oxometallic or peroxometallic acids:					
Chromates of lead and zinc	252	772	281	861	Japan (44%); Canada (22%); Norway (17%).
Sodium dichromate	10,300	5,860	10,500	5,920	United Kingdom (89%); Argentina (4%); Canada (4%).
Potassium dichromate	522	754	396	693	United Kingdom (44%); Russia (33%); Mexico (13%).
Other chromates and dichromates; peroxochromates	668	1,590	708	1,570	United Kingdom (88%); France (10%).
Chromium carbide	124	1,120	151	1,320	United Kingdom (46%); Japan (44%).
PIGMENTS AND PREPARATIONS BASED ON CHROMIUM					
Chrome yellow	3,610	8,000	5,080	11,400	Canada (62%); Hungary (13%); Mexico (12%).
Molybdenum orange	680	2,020	616	1,870	Canada (94%).
Zinc yellow	246	554	218	435	Norway (67%); Poland (27%).
Other	446	2,110	481	2,730	France (32%); Germany (29%); Canada (19%).

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.
2/ Contained 3,310 tons of chromium.
3/ Contained 5,260 tons of chromium.

Source: Bureau of the Census.

TABLE 19
AVAILABILITY OF CHROMITE AND CHROMIUM FERROALLOYS FROM 10 MARKET ECONOMY COUNTRIES

Chromium materials	Quantity available (million metric tons, gross weight)	Cost 1/ (dollars per metric ton)	
		Weighted average	Range
Chromite:			
Chemical grade	64.3	53	$35 - $174
Foundry sand grade	16.4	49	39 - 83
Metallurgical grade:			
Primary product	145.4	101	42 - 705
Secondary product	35.6	54	33 - 117
Subtotal	181.0	92	33 - 705
Refractory grade	26.8	87	54 - 180
Total	288.5		
Chromium ferroalloys:			
Ferrochromium:			
High-carbon ferrochromium	74.3	473	417 - 1,286
Low-carbon ferrochromium	3.9	937	635 - 1,309
Ferrochromium-silicon	2.0	737	578 - 814
Total	80.2		

1/ Cost of production for zero percent discounted cash-flow rate of return in Jan. 1989 dollars per metric ton, gross weight, of product f.o.b. at port of export.

Source: U.S. Bureau of Mines, Minerals Availability system cost analysis.

TABLE 20
PRINCIPAL WORLD CHROMITE PRODUCERS, 1994

Country 1/	Company
Albania	Albchrome (Government owned).
Brazil	Bayer AG (Germany)
	Coitezeiro Mineração S.A.
	Cia. de Ferro-Ligas da Bahia S.A.
	Cia. de Mineração Serra de Jacobina S.A.
	Mineração Vale do Jacurici S.A.
	Industria e Comércio de Minérios S.A.
	Invituruí Mineração S.A.
	Magnesita S.A.
	Piunhiense Mineração Ltda.
	Rada Mineração Ltda.
Finland	Outokumpu Oy (Government owned).
India	Ferro Alloys Corp. Ltd.
	Mysore Mineral Ltd.
	Orissa Mining Corp. Ltd. (Government owned).
	Tata Iron and Steel Co. Ltd.
Kazakhstan	Donskoy Ore Dressing Complex.
Philippines	Acoje Mining Co. Inc.
	Benguet Corp.
	Philchrome Mining Corp.
Russia	Saranov Complex.
South Africa, Republic of 2/	Anglovaal Ltd.
	Lavino (Pty.) Ltd.
	African Mining and Trust Co. Ltd.
	Zeerust Chrome Mine Ltd.
	Rustenburg Minerals Development Co. (Pty.) Ltd.
	Bayer (Germany).
	Chrome Chemicals SA (Pty.) Ltd.
	Canadian Gold S.A. (Pty.) Ltd.
	Goudini Chrome (Pty.) Ltd.
	Chromecorp Technology (Pty.) Ltd.
	Chroombronne (Pty.) Ltd.
	Genmin Ltd.
	Samancor Chrome Ltd.
	Batlhako Mining Ltd.
	Henry Gould (Pty.) Ltd.
	Millsell Chrome Mines (Pty.) Ltd.
	Montrose Mine.
	Groothoek Section.
	Jagdlust Section.
	Montrose Section.
	Mooinooi Mine.
	Tweefontein Mine.
	Waterkloof Mine.
	Winterveld Chrome Mines Ltd.
	Hernic Chrome
	Hernic Mining (Pty.) Ltd.
	Johannesburg Consolidated Investment Co.
	Consolidated Metallurgical Industries Ltd.
	Purity Chrome (Pty.) Ltd.
	Lebowa Development Corp. Ltd.
	Dilokong Chrome Mine (Pty.) Ltd.
	National Manganese Mines (Pty.) Ltd.
	Buffelsfontein Chrome Mine.
	Tolgate Group Holding (Pty.) Ltd.
	Pilanesberg Chrome (Pty.) Ltd.
	Vereeniging Refractories Ltd.
	Marico Chrome Corp. Ltd.
	Bophuthatswana Chrome Co. (Pty.) Ltd.
Turkey	Etibank (Government owned).
	Bursa Toros Kromlari AS.
	Egemetal Madencilik AS.
	Sitki Kocman Mines.
	Turk Maadin Sirketi AS.
	Hayri Ogelman Madencilik AS.
Zimbabwe	Zimbabwe Alloys Ltd.
	Zimbabwe Mining and Smelting Co. (Pvt.) Ltd.

1/ Other chromite-producing countries included Burma, China, Cuba, Egypt, Indonesia, Iran, Japan, Macedonia, Madagascar, Morocco, Oman, Pakistan, and Sudan.
2/ Includes Bophuthatswana.

TABLE 21
PRINCIPAL WORLD FERROCHROMIUM PRODUCERS, 1994

Country 1/	Company
Albania	Albchrome (Government owned).
Brazil	Cia. de Ferro-Ligas da Bahia S.A.
China	Chongqing Ferroalloy Works (Government owned).
	Emei Ferroalloy Works (Government owned).
	Hanzhong Ferroalloy Works (Government owned).
	Hengshan Iron and Steel Works (Government owned).
	Hunan Ferroalloy Works Government owned).
	Jiangyin Ferroalloy Works (Government owned).
	Jilin Ferroalloy Works (Government owned).
	Jinzhou Ferroalloy Works (Government owned).
	Liaoyang Ferroalloy Works (Government owned).
	Nanjing Ferroalloy Works (Government owned).
	Shanghai Ferroalloy Works (Government owned).
	Xibei Ferroalloy Works (Government owned).
Croatia	Tvornica Karbida i Ferolegura Dalmacija.
Finland	Outokumpu Oy (Government owned).
Germany	Gesellschaft für Elektrometallurgie mbH
	Elektrowerk Weisweiler GmbH.
India	Deepak Ferro-Alloys Ltd.
	Ferro-Alloys Corp. Ltd.
	Indian Metals & Ferroalloys Ltd.
	Indian Charge Chrome Ltd.
	Industrial Development Corp.
	Tata Iron and Steel Co. Ltd.
	OMC Alloys Ltd.
	Visvesvaraya Iron & Steel Ltd. (State owned)
Italy	Acciaierie e Ferriere Lombarde Falck SpA.
	Ferroleghe SpA.
Japan	Japan Metals and Chemicals Co. Ltd.
	Nippon Denko Co. Ltd.
	NKK Corp.
	Pacific Metals Co. Ltd.
	Showa Denko K.K.
Kazakhstan	Aktubinsk Ferroalloy Works.
	Yermakovsky Ferroalloy Works.
Norway	Elkem Rana.
Philippines	Ferrochrome Philippines Inc.
	Integrated Chrome Corp.
	Metro Alloys.
Russia	Chelyabinsk Electrometallurgical Works.
	Klyuchevsk Ferroalloy Works.
	Metroalloys.
	Serovsk Ferroalloy Works.
Slovenia	Tovarna Dusika Ruse.
South Africa, Republic of	Anglovaal Ltd.
	Feralloys Ltd.
	Chromecorp Technology (Pty.) Ltd.
	Johannesburg Consolidated Investment Co. Ltd.
	Consolidated Metallurgical Industries Ltd.
	Lydenburg Works.
	Rustenburg Works.
	Purity Ferrochrome (Pty.) Ltd.
	Genmin Ltd.
	Samancor Ltd.
	Batlhako Ferrochrome Ltd.
	Ferrometals Ltd.
	Middelburg Ferrochrome (Pty.) Ltd.
	Pamiet Ferrochrom (Pty.) Ltd.
	Tubatse Ferrochrome Division
Sweden	Vargön Alloy AB.
Turkey	Etibank (Government owned).
United States	Elkem Metals Co.
	Macalloy Corp.
Zimbabwe	Zimbabwe Alloys Ltd.
	Zimbabwe Mining and Smelting Co. (Pvt.) Ltd.

1/ Other ferrochromium-producing countries include Chile, Mexico, Poland, Romania, Spain and Taiwan.

TABLE 22
CHROMITE: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons, gross weight)

Country 3/	1990	1991	1992	1993	1994 e/
Albania	950,000 r/	587,000 r/	322,000 r/	282,000 r/	223,000 4/
Brazil 5/	263,000 r/	340,000	449,000 r/	308,000 r/	360,000 4/
Burma e/	1,000	1,000	6,200	1,000 r/	1,000
China e/	25,000	25,000	25,000	54,000 r/	50,000
Cuba e/	50,000	50,000	50,000	50,000	50,000
Egypt	399	649	600 e/	600 e/	600
Finland	504,000	473,000	499,000	511,000 r/	573,000 4/
Greece 6/	35,400	37,200	4,000 r/ e/	3,000 r/ e/	4,000
India	1,050,000 r/	940,000 r/	1,150,000 r/	1,000,000 r/	909,000 4/
Indonesia e/	8,000	1,950 4/	2,000	2,500	2,500
Iran 7/	77,200	90,100	130,000	130,000 r/ e/	129,000 4/
Japan e/	8,080 4/	8,000	8,000	7,000	7,000
Kazakhstan	XX	XX	3,500,000 r/	2,900,000	2,020,000 4/
Macedonia e/ 8/	XX	XX	6,000	5,000	5,000
Madagascar 7/	151,000 r/	149,000 r/	161,000 r/	144,000 r/	90,200 4/
Morocco	300	500	500	500 e/	500
New Caledonia	6,220	--	8,170 r/	-- e/	--
Oman	--	--	1,760	10,000 e/	6,200 4/
Pakistan	18,200	31,500	22,900	22,200 r/	23,000
Philippines	183,000 r/	191,000	65,700 r/	68,400 r/	68,900 4/
Russia e/	XX	XX	121,000	121,000 r/	143,000 4/
South Africa, Republic of 9/	4,620,000	5,100,000	3,360,000	2,830,000 r/	3,590,000 4/
Sudan e/	12,500 4/	10,000	10,000	10,000	10,000
Turkey 10/	836,000	940,000 e/	531,000	570,000 r/ e/	790,000
U.S.S.R. 11/	3,800,000	3,800,000 e/	XX	XX	XX
United Arab Emirates e/	--	--	1,000 r/	20,000 r/	25,000
Yugoslavia 8/ 12/	10,800	6,000 e/	XX	XX	XX
Zimbabwe	573,000	564,000	522,000	252,000 r/	517,000 4/
Total	13,200,000 r/	13,300,000	11,000,000	9,300,000	9,600,000

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

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

2/ Table includes data available through June 29, 1995.

3/ Figures for all countries represent marketable output unless otherwise noted.

4/ Reported figure.

5/ Average Cr2O3 content was as follows: 1990--39.2% (revised); 1991--41.9% (revised); 1992--44.1% (revised); 1993--41.0% (revised); and 1994--41.3%.

6/ Direct-shipping ore plus concentrate.

7/ Concentrate.

8/ All production in Yugoslavia from 1990-91 came from Macedonia.

9/ Includes production by Bophuthatswana.

10/ Salable product: direct-shipping lump ore plus concentrate.

11/ Dissolved in Dec. 1991.

12/ Dissolved in Apr. 1992.

TABLE 23
FERROCHROMIUM: WORLD PRODUCTION, BY COUNTRY 1/ 2/

(Metric tons)

Country	1990	1991	1992	1993	1994 e/
Albania	24,000	25,000	22,000 r/	36,000 r/	34,000
Brazil 3/	83,800	82,200	91,100 r/	83,900 r/	77,100 4/
Chile	1,870	2,510	2,110 r/	680 r/	1,580 4/
China e/	340,000 r/	380,000 r/	410,000 r/	372,000 r/	370,000
Croatia	XX	XX	56,500	27,300	32,000
Czechoslovakia 3/ 5/	37,500 r/	41,200 r/	52,500 r/	XX	XX
Finland	157,000	190,000	187,000	218,000	229,000 4/
France e/	25,000	23,100	6,690 4/	--	--
Germany:					
Eastern states	21,000 e/	XX	XX	XX	XX
Western states	37,500 e/	XX	XX	XX	XX
Total	58,500 e/	38,300 r/	26,500	16,400	17,300 4/
Greece	30,300	10,500 e/	--	--	--
India 6/	169,000	229,000 r/	257,000	235,000 r/	251,000 4/
Iran 7/	--	--	--	--	5,000
Italy	53,000	47,200	60,300	53,500	22,700
Japan 3/	304,000	279,000	276,000	211,000 r/	203,000 4/
Kazakhstan	XX	XX	400,000 e/	328,000 r/	185,000
Macedonia	XX	XX	3,960	4,380	3,160 4/
Mexico	275	72	70 e/	-- r/	--
Norway	60,000	83,000	102,000	80,000	120,000 4/
Philippines	55,700 r/	23,700	27,400	11,900 r/	16,200 4/
Poland	13,700	1,930	35,300	38,400	7,000
Romania	20,600	20,400	6,980	3,910	3,900 4/
Russia	XX	XX	400,000	256,000 r/	266,000 4/
Slovakia 3/ 4/	XX	XX	XX	50,600 r/	48,500 4/
Slovenia	XX	XX	17,100	9,000	12,600
South Africa, Republic of 8/ 9/	1,020,000	1,150,000 r/	771,000 r/	834,000 r/	1,100,000 4/
Spain e/	15,000	6,000	--	2,390 4/	2,000
Sweden	118,000	121,000	133,000	128,000	134,000 4/
Turkey	62,000 r/	84,700	85,800	90,000	97,600 4/
U.S.S.R. e/ 10/	700,000	700,000	XX	XX	XX
United States 11/	109,000	68,300	60,900	63,000	67,400 4/
Yugoslavia 12/	82,700	91,000	XX	XX	XX
Zimbabwe 3/	222,000	187,000	191,000	130,000 r/ e/	190,000
Total	3,760,000 r/	3,880,000 r/	3,680,000 r/	3,280,000 r/	3,500,000

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

1/ Previously published and 1994 data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

2/ Table includes data available through June 29, 1995.

3/ Includes high- and low-carbon ferrochromium.

4/ Reported figure.

5/ Czechoslovakia was dissolved on Dec. 31, 1992. All production in Czechoslovakia from 1990-92 came from Slovakia.

6/ Includes ferrochrome and charge chrome.

7/ Production began in 1994. Plant capacity is estimated at 7,000 tons per day.

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

9/ Includes production from Bophuthatswana.

10/ Dissolved in Dec. 1991.

11/ Includes high- and low-carbon ferrochromium, ferrochromium-silicon, chromium metal, and other chromium materials.

12/ Dissolved in Apr. 1992.

TABLE 24
WORLD CHROMIUM ANNUAL PRODUCTION CAPACITY OF CHROMITE ORE,
FERROCHROMIUM, CHROMIUM METAL, CHROMIUM CHEMICALS, AND STAINLESS STEEL IN 1994 1/

(Thousand metric tons, contained chromium)

	Ore	Ferro-chromium	Metal	Chemicals	Stainless steel
Albania	150	32	--	--	--
Argentina	--	--	--	6	NA
Austria	--	--	--	--	12
Bangladesh	--	--	--	--	3
Belgium	--	--	--	--	75
Brazil	135	89	(2/)	12	37
Burma	(2/)	--	--	--	--
Canada	--	--	--	--	32
Chile	--	2	--	--	--
China	13	200	5	16	68
Croatia	--	42	--	--	--
Cuba	14	--	--	--	11
Czech Republic	--	--	--	--	NA
Egypt	1	--	--	--	--
Finland	211	115	--	--	73
France	--	--	5	--	156
Germany	--	76	1	20	255
Greece	21	--	--	--	--
India	309	167	(2/)	5	45
Indonesia	20	--	--	--	--
Iran	34	4	--	2	--
Italy	--	64	--	--	146
Japan	3	178	1	21	595
Kazakhstan	1,100	330	--	42	--
Korea, North	--	32	--	--	--
Korea, Republic of	--	--	--	--	94
Macedonia	3	7	--	5	--
Madagascar	21	--	--	--	--
Mexico	--	2	--	--	NA
Norway	--	88	--	--	--
Oman	4	--	--	--	--
Pakistan	10	--	--	3	--
Philippines	60	60	--	--	--
Poland	--	16	--	7	NA
Romania	--	26	--	5	NA
Russia	40	233	16	63	330
Slovakia	--	30	--	--	--
Slovenia	--	8	--	--	NA
South Africa, Republic of	1,600	794	--	--	30
Spain	--	--	--	--	112
Sudan	2	--	--	--	--
Sweden	--	97	--	--	105
Taiwan	--	1	--	--	28
Thailand	(2/)	--	--	--	--
Turkey	300	103	--	10	54
Ukraine	--	--	--	--	33
United Arab Emirates	8	--	--	--	--
United Kingdom	--	--	5	68	94
United States	--	83	3	55	330
Zimbabwe	170	133	--	--	--
Total	4,230	3,010	39	340	2,720

NA Not available.

1/ Data are rounded by the U.S. Bureau of Mines to three significant digits; may not add to totals shown.

2/ Less than 1/2 unit.