TITANIUM

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Titanium occurs primarily in the minerals anatase, brookite, ilmenite, leucoxene, perovskite, rutile, and sphene. Of these minerals, only ilmenite, leucoxene, and rutile have significant economic importance. As a metal, titanium is well known for corrosion resistance and for its high strength-to-weight ratio. Approximately 95% of titanium is consumed in the form of titanium dioxide (TiO₂), a white pigment in paints, paper, and plastics. This pigment is characterized by its purity, refractive index, particle size, and surface properties. To develop optimum pigment properties, the particle size is controlled within the range of about 0.2 to 0.4 micrometer. The superiority of TiO₂ as a white pigment is due mainly to its high refractive index and resulting light-scattering ability, which impart excellent hiding power and brightness.

Global consumption of TiO_2 pigment decreased slightly in 1998. Consumption in Asia was down significantly. Consumption in Europe and North America, however, remained near record levels. Consequently, global consumption of titanium mineral concentrates (ilmenite, rutile, slag, and synthetic rutile) was nearly unchanged compared with that of 1997. On a gross weight basis, apparent consumption of TiO₂ in the United States was nearly unchanged compared with that of 1997 (table 1).

Legislation and Government Programs

During 1998, the Defense National Stockpile Center continued to solicit offers for the sale of titanium sponge held in the Government stockpile. In the fiscal year 1998, sales of titanium sponge totaled 1,140 metric tons (t) with a value of \$4.36 million. At the end of fiscal year, 31,700 t of sponge remained in the stockpile.

In accordance with section 3305 of the National Defense Authorization Act for fiscal year 1996 (P.L. 104-106), 250 t of titanium sponge were transferred to the Army's Tank and Automotive Command for use in the weight reduction portion of the main battle tank upgrade program. The market value of this material was estimated to be \$2 million. Fiscal year 1998 was the third year of this program, which provides for annual transfers of up to 250 t of titanium sponge to continue through fiscal year 2003. By the end of 1998, 750 t have been transferred. Although this material was provided to the Army without charge, the law specifies that the Army will pay the costs for transportation and handling (U.S. Department of Defense, 1999, p. 7 and 13).

Production

Mineral Concentrates.—Commercial forms of titanium mineral concentrates include ilmenite, leucoxene, rutile, slag, and synthetic rutile. Australia, Canada, Norway, and South Africa were the major producing countries of titanium mineral concentrates. U.S. producers included E.I. du Pont de Nemours & Co. Inc. (DuPont), Kerr-McGee Chemical Corp., RGC (USA) Mineral Sands, Inc., and Vulcan Materials Co. DuPont's Trail Ridge mining operations in Starke, FL, produced a mixed product containing ilmenite, leucoxene, and rutile which was used as a feedstock in DuPont's titanium pigment operations. RGC's mining operations in Green Cove Springs, FL, and Stony Creek, VA, produce both rutile and ilmenite concentrates. Vulcan Materials, formerly P.W. Gillibrand Co., produced ilmenite concentrate as a byproduct of its sand and gravel operation in Simi Valley, CA. Kerr McGee's operation in Mobile, AL, produced synthetic rutile from purchased ilmenite concentrate. Titanium slag was not produced in the United States.

Altair International Inc. prepared to complete a prefeasibility study of the Camden, TN, mineral sands deposit. According to the company, the 300-million-metric-ton (Mt) deposit contains an indicated resource of about 12 Mt of heavy minerals, including 7.4 Mt of leucoxene/ilmenite and 600,000 t of rutile (Altair International Inc., July 14, 1998, Management discussion on Camden pre-feasibility study, press release, accessed May 5, 1998, at URL http://www.altairint.com/ news98.html).

Metal.—Titanium sponge is the primary metal form of titanium. Production involves the chlorination of titanium-containing mineral feedstocks to produce titanium tetrachloride (TiCl₄). Titanium tetrachloride is purified and then reacted with magnesium to produce titanium sponge. Titanium sponge is produced in China, Japan, Kazakhstan, Russia, and the United States. U.S. producers of titanium sponge included Johnson Matthey Refining Inc., a subsidiary of Johnson Matthey plc.; Oremet-Wah Chang, an Allegheny Teledyne Inc. company; and Titanium Metals Corp. (TIMET). Domestic operating capacity of titanium sponge was estimated to be 21,600 metric ton per year (t/yr). Data on domestic production of titanium sponge have not been published in order to avoid disclosing company proprietary data (table 2).

Titanium ingot is produced by melting titanium sponge or scrap or a combination of both, usually with various other

alloying elements, such as aluminum and vanadium. Electron beam, plasma, and vacuum arc reduction (VAR) are the current (1998) commercial melting methods used to produce ingot. In 1998, commercial ingot production capacity existed in France, Germany, Japan, Russia, the United Kingdom, and the United States. In the United States, ingot was produced by 5 companies in 12 locations. U.S. production of ingot decreased by about 6% compared with that of 1997 (table 3).

Titanium mill products result from the drawing, forging, and rolling of titanium ingot or slab into products of various sizes and shapes. These mill products include titanium billet, bar, rod, wire, plate, sheet, strip, extrusions, pipe and tube, etc. Major producers of titanium mill products were located primarily in China, Europe, Japan, Russia, and the United States. More than 30 domestic companies were known to produce titanium mill products and castings from ingot and billet. In 1998, U.S. production of mill products decreased by 7% compared with that of 1997.

Titanium castings are produced by melting titanium ingot or billet and then pouring the molten metal into a mold. U.S. producers of titanium castings included Coastcast Corp., Duriron Co., Howmet Corp., Investicast, Ltd., Precision Cast Parts Corp., Selmet Inc., and Wyman-Gordon Investment Castings, Inc.

Ferrotitanium is produced through induction melting of titanium scrap with iron or steel. U.S. producers of ferrotitanium included Galt Alloys Inc. and Shieldalloy Metallurgical Corp. The two standard grades of ferrotitanium contain 40% and 70% titanium. Data on production of ferrotitanium was not available.

In July, RMI Titanium Company acquired New Century Metals Inc. (NCM) and Weld-Tech Engineering Services L.P. NCM manufactured and distributed high-temperature and corrosion-resistant alloys, including titanium, to such industries as the aerospace, chemical processing, oil exploration and production, and power generation. Weld-Tech provided engineering and fabrication services to the oil and gas industry (RMI Titanium Company, 1998c). In August, RMI announced the formation of a holding company named RTI International Metals Inc. Under the corporate restructuring, RMI became a wholly owned subsidiary of RTI (RMI Titanium Company, 1998b). In October, RMI and the United Steelworkers of America failed to reach agreement on a contract covering the hourly workers at its Niles, OH, plant. A work stoppage began on October 1 and continued into 1999. According to the company, titanium ingot and mill products were being produced by salaried personnel at about 40% to 50% of normal production while negotiations continued (RMI Titanium Company, 1998a). In December, RMI announced that, owing to improved operating practices and reduced aerospace demand, it was permanently shutting down two of the six vacuum arc furnaces used to produce titanium ingot at the Niles plant. The shutdown was expected to result in the elimination of approximately 25 jobs (RMI Titanium Company, 1998d).

TIMET exchanged certain castings assets for Wyman-Gordon Co.'s VAR ingot melting operations in Millbury, MA. The two companies combined their castings businesses into a new joint venture that is 80% owned by

Wyman-Gordon and 20% owned by TIMET. Under an agreement between the two companies, TIMET will become the principal titanium supplier to Wyman-Gordon through 2008. In Europe, TIMET acquired Italian mill product producer Loterios, S.p.A. Loterios was a producer and distributor of titanium pipe and fittings for the oil and gas and chemicalprocess industries. Titanium Hearth Technologies Inc., a TIMET subsidiary, commissioned a new melting furnace at its Morgantown, PA, operation. The new furnace was expected to produce up to 10.000 t/vr of titanium ingot by using electron beam technology. In addition, new VAR melting capacity was expected to be operational in Morgantown by the end of the first quarter of 1999. The new VAR furnace capacity was expected to exceed 4,500 t/yr (Titanium Metals Corp., March 18, 1999, Production - Advancing titanium technology and capacity, annual report, accessed May 22, 1999, at URL http://www.timet.com/pdfs/ 98annual.pdf).

Oremet-Wah Chang commissioned its International Hearth Melting (IHM) facility at Richland, WA. The IHM facility was expected to produce up to 10,000 t/yr of titanium ingot by using electron beam technology.

Wyman-Gordon and International Extruded Products, LLC (IXP) announced that they had entered into an agreement in which Wyman-Gordon would acquire IXP. IXP was a specialty manufacturer of extruded seamless wall pipe used in the power generation, oil and natural gas, and petrochemical industries. Consumption of titanium was expected to increase in these industries (Wyman-Gordon Co., April 16, 1998, accessed August 24 1999 at URL http://www.wyman-gordon.com/ company/news/pr041698.htm).

Metal Management Inc. acquired Aerospace Metals Inc., a major processor of titanium scrap and superalloys based in Hartford, CT. Aerospace Metals recently increased its ability to process titanium turnings by 50%. Metal Management was a company in the scrap metal industry whose subsidiary companies included an variety of ferrous metals recycling operations (Metal Management Inc., January, 21, 1998, Metal Management completes acquisition of one of the world's leading recyclers of super alloys and titanium, press release, accessed on May 11, 1998, at URL http://biz.yahoo.com/ prnews/980121/il_metal_m_1.html).

Pigment.—Titanium dioxide pigments are produced as two major types; rutile and anatase. Rutile and anatase pigments are chemically similar but differ in crystal form. Rutile-type pigment is less reactive with the binders in paint when exposed to sunlight than is the anatase type and is preferred for use in outdoor paints. Anatase pigment has a bluer tone than the rutile type, is somewhat softer, and is used mainly in indoor paints and in paper manufacturing. Depending on the manner in which titanium pigment is produced and subsequently finished, titanium pigments can exhibit a range of functional properties, including opacity, durability, dispersion, and tinting.

Titanium dioxide pigment is produced by using either the chloride process or the sulfate process. Although either process may be used to produce rutile or anatase-grade pigments, the decision to use one process over the other is based on a number of factors, including raw material availability, freight, and waste disposal costs.

In the sulfate process, ilmenite or titanium slag is reacted with sulfuric acid, and a portion of the iron sulfate formed may be crystallized and removed. Titanium hydroxide is precipitated by hydrolysis, filtered, and calcined.

In the chloride process, rutile is converted to TiCl_4 by chlorination at 850° to 950° C in the presence of petroleum coke. Titanium tetrachloride may be used either in making pigment or, with additional purification, for reduction to metal. In making pigment, the TiCl_4 is oxidized with air or oxygen at about 1,000° C, and the resulting fine-size TiO_2 is calcined at 500° to 600° C to remove residual chlorine and any hydrochloric acid that may have formed in the reaction. Aluminum chloride is added to the TiCl_4 to assure that virtually all the titanium is oxidized in the rutile crystalline form.

Recoveries of TiO_2 in pigment are approximately 80% to 90%. The crude form of the pigment is milled to produce a controlled distribution of particle size and surface treated or coated to improve its functional behavior in different media. Some typical surface treatments include alumina, silica, and organic treatments.

U.S. producers of titanium dioxide pigments were DuPont, Kemira Pigments, Kerr-McGee, Louisiana Pigment Co. LP, and Millennium Inorganic Chemicals Inc. (MIC) (table 4). In 1998, U.S. production of TiO₂ pigment decreased slightly compared with that of 1997 (table 5). Capacity use for the domestic pigment industry was about 91%.

Kerr-McGee was expanding capacity at its Hamilton, MS, pigment plant. The expansion was scheduled for completion in 1999 and will increase capacity to 178,000 t. (Kerr-McGee Chemical Corp., Kerr-McGee reports 1998 accomplishments and 1999 plan at annual meeting, news release, May 11, 1999, accessed August 24, 1999, at URL http://www.kerr-mcgee.com/Pages/1998/98ar.htm).

Consumption

Mineral Concentrates.—Owing to changes in reporting methods, the aggregated consumption titanium mineral feedstocks are not comparable with those of 1997. On a gross weight basis, U.S. reported consumption of TiO_2 in ilmenite and titanium slag was 1.3 Mt. Consumption of natural and synthetic rutile decreased by 14% compared with that of 1997.

Consumption data for titanium concentrates are developed by the U.S. Geological Survey from one voluntary survey of domestic operations. Of the 26 operations canvassed, 21 responded, representing 99% of the data in table 6. Data for nonrespondents were estimated on the basis of prior-year consumption levels (table 6).

Metal.—Decreased demand from commercial aircraft resulted in a slight-to-moderate decrease in demand for titanium metal products. Overall consumption of titanium sponge and scrap decreased by about 2% compared with that of 1997. Although scrap consumption increased by about 8% compared with that of 1997, sponge consumption fell by about 10%. Scrap supplied a calculated 50% of ingot feedstock, a 10% increase compared with that of 1997. Falling demand for titanium mill products by the commercial aerospace and nonaerospace markets resulted in a slight decrease in ingot consumption and an 8% decrease in net shipments of mill products. Reported shipments of titanium castings decreased by 11%. Estimated U.S. mill product usage by application was as follows: aerospace, 65%, and nonaerospace uses, 35%. Nonaerospace uses included those in the specialty chemical, pulp and paper, oil and gas, marine, medical, and consumer goods industries. Reported consumption of titanium products in steel and other alloys decreased by 14% compared with revised data for 1997 (tables 3 and 7).

Pigment.—Titanium dioxide pigments accounted for more than 95% of all prime white pigments. The three largest end uses were paint and coatings, paper, and plastics. Other consuming industries included ceramics, fabrics and textiles, floor coverings, printing ink, and rubber. In 1998, apparent domestic consumption of TiO₂ pigments was about 1.14 Mt, nearly unchanged compared with that of 1997 (tables 5 and 8). The paint, varnish, and lacquer was followed by plastic, then paper, as the largest end use industries for domestic shipments of pigment (table 8).

In the paint and coatings market, TiO_2 is used in white and color formulations. The industry is largely made up of equipment, architectural, and special-purpose applications. The equipment portion of the market includes automotive, appliances, containers, and wood. Equipment applications require high brightness, gloss, and durability, as well as resistance to abrasion, heat, and chemical attack. Architectural applications include interior and exterior coatings, as well as lacquers and stains. Architectural applications demand high durability, gloss, and hiding power. Special purpose coatings include marine, traffic, refinish, and aerosol coatings. The TiO₂ content for paint and coatings varies.

The plastics industry primarily consumes rutile-grade pigment. Titanium dioxide pigments represent the majority of all inorganic pigments used in the plastics industry. Titanium dioxide pigments are used in the plastics industry in a variety of applications. They serve to provide opacity and act as barrier against ultraviolet light degradation. Most TiO₂ pigments are introduced as pelletized concentrates containing up to 50% by weight TiO₂ in a carrier resin. Liquid and dry concentrates also are used by the industry. The final TiO₂ content normally ranges from 3% to 25% by weight of the finished product.

Titanium pigments are used in paper products to give opacity and brightness. Anatase-grade pigment is often used in the paper industry because it is less abrasive to papermaking machinery. The paper industry consumes TiO_2 pigments as filler and in coatings. Although paper products contain a high percentage of minerals as filler material, the typical TiO_2 content is estimated to be less than 5% of the dry weight of paper.

Stocks

On a gross weight basis, yearend consumer inventories of titanium mineral concentrates increased by 27% compared with those of 1997 (table 9). Meanwhile, producer stocks of TiO_2 pigment were about 96,900 t, a 10% decrease from those of 1997. Compared with those of 1997, industry stocks of sponge

increased by 51%, stocks of titanium scrap decreased by 11%, and stocks of titanium ingot decreased by 7%.

Prices

In general, prices of titanium mineral concentrates were moderately lower in 1998 compared with those of 1997. The yearend published price range for bulk rutile concentrates was \$470 to \$530 per ton, an average decrease of 5% compared with that of 1997. The price range for bagged rutile concentrates used in the welding rod coatings market was \$570 to \$620 per ton, an average decrease of 13% compared with that of 1997. Ilmenite prices were nearly unchanged with a yearend range of \$72 to \$77 per ton (Industrial Minerals, 1998d). Published prices for titanium slag were not available. On the basis of the U.S. Customs value of imports, however, prices for Canadian slag increased by 10%, and prices for South African slag decreased slightly compared with those of 1997 (table 10).

Foreign Trade

Mineral Concentrates.—In 1998, the United States was highly dependent on imported titanium mineral concentrates. The largest import sources of titanium concentrates were Australia, Canada, India, Norway, and South Africa. Imports of ilmenite, rutile, slag, and synthetic rutile concentrates were, in tons, 379,000, 246,000, 626,000, and 141,000, respectively. Exports of titanium mineral concentrates were 59,700 t, a 151% increase compared with those of 1997 (table 11). Overall, imports of titanium concentrates (on a gross weight basis) increased by 10% compared with those in 1997 (table 12).

Metal.—U.S. import reliance extended to titanium metal, primarily in the form of titanium sponge and scrap. Although a significant quantity of imported titanium scrap was consumed by the iron and steel industry, nearly all the imported sponge was consumed by the titanium industry. Owing to decreased demand for commercial aircraft, sponge imports decreased by 32% compared with those of 1997. The leading import sources of titanium sponge were China, Japan, Kazakhstan, and Russia. The leading import sources of titanium waste and scrap were France, Japan, Russia, and the United Kingdom (table 13).

Pigment.—Although the United States was a net exporter of titanium pigments, a significant quantity of titanium pigments was imported. During 1998, pigment imports increased by 3%, and the leading import sources of titanium pigments were Canada and Germany. Compared with those of 1997, imports of titanium pigments containing more than 80% TiO₂ totaled 152,000 t, a 14% increase; other titanium pigments, 22,100 t, a 44% decrease; titanium oxide, 25,800 t, a 21% increase (table 14). In 1998, exports of titanium pigments were 356,000 t, a slight decrease compared with those of 1997. Exports of titanium oxides (unfinished pigments) were 42,200 t, a slight decrease compared with those of 1997.

World Review

In 1998, Australia, Canada, India, Norway, and South Africa continued to lead the world's production of titanium mineral concentrates (table 15). Production of slag from Canada and South Africa increased about 5% over 1997. World production of natural rutile, excluding the United States, decreased slightly.

Australia.—RGC Ltd. and Westralian Sands Ltd. planned to merge. When completed, the new company would become the second largest producer of titanium concentrates after Rio Tinto plc. Under the merger, RGC Ltd. shareholders will hold a 62% interest in the new company, and Westralian shareholders will have the remaining 38%. RGC continued its exploration in the Murray Basin. In 1998, the company was conducting a prefeasibility study of the deposits in Kulwin and Woornack in New South Wales.

The Broken Hill Proprietary Company Ltd. (BHP) declared force majeure at its Beenup operation in Western Australia. The decision followed an extensive study into the technical problems caused by the high clay content of the Beenup ore body that has affected the management of tailings and the mine's ability to reach satisfactory levels of production. Beenup had begun operations in January 1997. Operations ceased in April 1998 (Broken Hill Proprietary Company Ltd., August 11, 1999, BHP report to shareholders 98, accessed August 24, 1999, at URL http://www.bhp.com.au/financials/ pdf/98bhprts.pdf).

Consolidated Rutile Ltd. planned to halt mining at its Gordon operation and move the dredge and floating concentrator into its Yarraman reserves on North Stradbroke Island in Queensland. During the move, the concentrator will be upgraded to increase production with better mineral recoveries. The move was expected to begin in March 1999 and to be completed in 30 weeks (Industrial Minerals, 1998c).

Nimbus Resources NL signed a memorandum of understanding with BHP to acquire the Hawks Nest mineral sands operation in New South Wales. Under the agreement, Nimbus will also gain the rights to use the name Mineral Deposits Ltd. (Industrial Minerals, 1998a).

Bemax Resources NL was delineating resources of heavy minerals at its Murray Basin mineral sands project in New South Wales. A drilling program was begun in the Nanya-Plain Tank area and was expected to be complemented with an aeromagnetic survey covering more than 2,000 square kilometers (Minerals Gazette, 1998).

Belgium and Germany.—Kerr-McGee and Bayer AG agreed to form a joint venture whereby Kerr-McGee would acquire 80% interest in Bayer's TiO_2 business. The agreement will encompass all Bayer's marketing, research and development, and production operations, excluding its minority interest in Titâno do Brasil, S.A. Bayer's production facilities include two sulfate-route pigment facilities located in Uerdingen, Germany, and Antwerp, Belgium, with a combined capacity of 135,000 t/yr (Bayer AG, Joint venture secures market position, April 1998, accessed May 11, 1998, at URL http://www.bayer.com/ bayer/ueberblick/investor_relations/geschaeftsbericht_1998/ nachrichten_en.html).

Brazil.—MIC entered into an agreement to purchase the majority interest of Brazilian TiO_2 producer Titânia dō Brasil S.A. (Tibras). Tibras operations include a 60,000-t/yr sulfate-route pigment plant and a heavy mineral sands operation with an estimated 2 Mt of recoverable reserves (Millennium Chemicals Inc., 1998).

Canada.—Shipments of chloride-grade slag from QIT-Fer et Titane Inc.'s upgraded slag plant at Sorel, Quebec, began in 1998 (Rio Tinto plc., Industrial mineral group operational review 1998, March 5, 1999, accessed August 23, 1998, at URL http://www.riotinto.com/98ara01_b.pdf). U.S. imports of slag from Canada went to 103,000 t in 1998 from 49,700 t in 1997. Exploration activities in Canada included Titanium Corp. of Canada Ltd. examination of a heavy mineral sands deposit near Truro, Nova Scotia. Initial drilling and surface prospecting suggested that 25 Mt of heavy minerals were present in sufficient quantities to warrant a more thorough assessment (Titanium Corp. of Canada Ltd., 1998).

France.—Millennium Chemicals Inc. acquired Thann et Mullhouse S.A., a subsidiary of Rhône-Poulenc S.A.. Thann's operations included two sulfate-route titanium pigment and specialty chemical operations in Le Havre and Thann, France, with pigment capacities of 33,000 and 105,000 t/yr, respectively. Thann will be incorporated into Millennium Chemicals subsidiary, MIC, which was the world's second largest titanium pigment producer with 611,000 t/yr of capacity (Millennium Chemicals Inc., Millennium Chemicals completes purchase of Rhone-Poulenc's Thann et Mulhouse S.A. Positioned as the world's second largest titanium dioxide producer, press release, January 5, 1998, accessed May 11, 1998, at URL http://www.millenniumchem.com/ne/news/ mchrhone.htm).

India.—Kerala Metals and Minerals Ltd. announced plans to increase mineral separation and pigment capacities at its Kerala operation. Initially, the company planned to build its own power-generation facility and to raise the capacity of its mineral separation facility to 120,000 t/yr. Subsequent plans will be to increase the capacity of its 22,000-t/yr pigment plant; the company did not specify how large an expansion of pigment capacity was planned (Industrial Minerals, 1998e).

Kenya.—Tiomin Resources Inc. continued its examination of five mineral sands deposits in Kenya. In 1998, Tiomin completed a prefeasibility study of the Kwale deposit and finalized designs for the separation and processing plant. According to Tiomin, the Kwale deposit was estimated to contain a resource of 4 Mt of ilmenite and 1 Mt of rutile. A full feasibility study was expected to be completed in 1999 (Tiomin Resources Inc., 1999).

Mozambique.—Billiton plc. concluded a preliminary feasibility study at its TiGen deposit in northern Mozambique. Owing to market conditions, the company decided to delay any further development of the project. Another exploration included a site at Naburri. Combined reserves for the Naburri and the TiGen and deposits are reported to be 31 Mt of TiO₂ (Industrial Minerals, 1998b).

South Africa.—Anglo American Corp. neared completion of a second slag furnace at its Namakwa Sands operation. Commissioning of the furnace was scheduled for 1999. When fully operational, the expansion was expected to increase plant capacity to 235,000 t/yr (Mineral Sands Report, 1999).

Iscor Ltd. deferred development of its KwaZulu-Natal heavy minerals project near Richards Bay until the second half of 1999. In 1998, the company received approval of its environmental management report from the Department of Minerals and Energy. Iscor has been granted most of the necessary mining permits to begin the project; approval for solid waste disposal and licensing in accordance with nuclear safety are still pending (Zululand Observer, October 9, 1998, Iscor smelter delayed, accessed August 24, 1999, at URL http://www.iscorltd.co.za/ihm/press_articles/98100901.htm).

United Kingdom.—At MIC's Stallingborough operation, TiO₂ pigment capacity was being expanded. By 1999, capacity at the chloride-route facility will increase from 119,000 to 150,000 t/yr (Millennium Chemicals Inc., 1998).

Outlook

Owing to increased demand from titanium pigment producers, mineral concentrate producers are in the process of substantially increasing the supply of high-grade mineral concentrates suitable for use by chloride-route titanium pigment producers. Within the past 2 years, several projects were commissioned to upgrade existing feedstock sources. As a result of these upgrades, new chloride-grade slag production capacity exists in Canada, Norway, and South Africa, which had been the exclusive source of chloride-grade slag. During the next few years, the development of new programs in Australia and South Africa will substantially increase the availability of titanium concentrates. As has been the case for several years, the ability of Sierra Leone to resume production of natural rutile remains unclear. Exploration and development activities are ongoing in Australia, Canada, Kenya, Madagascar, Russia, South Africa, Sri Lanka, and the United States. On a global basis, adequate mineral supplies of TiO_2 exist or are being developed to meet increased demand over the next decade. Consumption of TiO₂ is linked to the growth of the overall economy. During the next decade, U.S. demand for TiO₂ pigment is expected to grow at an annual rate of 2% to 3%.

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TABLE 1 SALIENT TITANIUM STATISTICS 1/

(Metric tons unless otherwise specified)

	1994	1995	1996	1997	1998
United States:					
Ilmenite and titanium slag:					
Imports for consumption	808,000	861,000	939,000	952,000	1,010,000
Consumption	W	1,410,000 2/	1,400,000 2/	1,520,000 2/	1,300,000 3/
Rutile concentrate, natural and synthetic:					
Imports for consumption	332,000	318,000	324,000	336,000	387,000
Consumption	510,000	480,000	398,000	489,000 r/	421,000
Sponge metal:					
Imports for consumption	6,470	7,560	10,100	16,100	10,900
Consumption	17,200	21,500	28,400	31,300 r/	28,200
Price, December 31, per pound	\$3.75-\$4.25	\$4.24-\$4.50	\$4.25-\$4.50	\$4.25-\$4.50	\$4.25-\$4.50
Titanium dioxide pigment:					
Production	1,250,000	1,250,000	1,230,000	1,340,000	1,330,000
Imports for consumption	176,000	183,000	167,000	194,000	200,000
Consumption, apparent 4/	1,090,000	1,130,000	1,070,000	1,130,000	1,140,000
Price, December 31, dollars per pound:					
Anatase	\$0.94-\$0.96	\$0.92-\$0.96	\$1.06-\$1.08	\$1.01-\$1.03	\$0.96-\$0.98
Rutile	\$0.92-\$0.94	\$0.92-\$0.96	\$1.08-\$1.10	\$1.04-\$1.06	\$0.97-\$0.99
World production:					
Ilmenite concentrate	3,970,000 r/ 5/	4,010,000 r/ 5/	4,010,000 r/ 5/	4,070,000 r/ 5/	4,650,000 e/ 6/
Rutile concentrate, natural	545,000 r/ 5/	416,000 5/	366,000 r/ 5/	427,000 r/ 5/	426,000 e/ 6/
Titaniferous slag	1,510,000	1,810,000	1,830,000	1,950,000 r/	2,050,000 e/

e/ Estimated. r/ Revised. W Withheld to avoid disclosing company proprietary data.

1/ Data are rounded to three significant digits; except prices.

2/ Includes consumption to produce synthetic rutile.

3/ Excludes ilmenite used to produce synthetic rutile.

4/ Production plus imports minus exports plus stock decrease or minus stock increase.

5/ Excludes U.S. production data to avoid disclosing company proprietary data.

6/ U.S. production of natural and synthetic rutile included with ilmenite concentrate.

TABLE 2 U.S. TITANIUM METAL PRODUCTION CAPACITY IN 1998 1/2/

		Yearend of	capacity	
		(metric	(metric tons)	
Company	Plant location	Sponge	Ingot 3/	
Allegheny Teledyne Inc.	Albany, OR	6,800	10,900	
	Monroe, NC		11,800	
	Richland, WA		10,000	
Howmet Corp.	Whitehall, MI		3,200	
Johnson Matthey plc.	Salt Lake City, UT	340		
Lawrence Aviation Industries Inc.	Port Jefferson, NY		1,400	
RMI Titanium Company	Niles, OH		16,300	
Titanium Metals Corp.	Henderson, NV	14,500	15,900	
	Morgantown, PA		20,400	
	Vallejo, CA		450	
	Worcester, MA		2,300	
Total		21,600	92,700	

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

2/ Operating capacity based on 7-day-per-week full production.

3/ Includes electron beam, plasma, and vacuum arc reduction capacity.

TABLE 3

COMPONENTS OF U.S. TITANIUM METAL SUPPLY AND DEMAND 1/

(Metric tons)

Component	1997	1998
Production:		
Ingot	55,900 r/	52,500
Mill products	35,900 r/	33,400
Exports:		
Sponge	976	348
Other unwrought	429	791
Scrap	5,500	7,010
Ingot, slab, sheet bar, etc.	4,310	3,080
Other articles of titanium	5,200	5,800
Total	16,400	17,000
Imports:		
Sponge	16,100	10,900
Scrap	10,700	9,770
Ingot and billet	5,410	2,240
Other unwrought	244	410
Other wrought (mill products)	4,270	3,160
Other articles of titanium	323	744
Total	37,000	27,200
Stocks, yearend:		
Government: Sponge (total inventory)	33,100	31,700
Industry:		
Sponge	7,020 r/	10,600
Scrap	15,200	13,600
Ingot	4,350	4,050
Total	26,600	28,200
Reported consumption:		
Sponge	31,300 r/	28,200
Scrap	26,300 r/	28,600
Receipts:		
Home	15,600	13,800
Purchased	20,300	21,600
Ingot	43,400 r/	43,000
Mill products (net shipments):	29,800 r/	27,500
Forging and extrusion billet	12,500 r/	11,200
Rod and bar	3,850 r/	3,700
Other 2/	13,500 r/	12,600
Castings (shipments)	1,020	908

r/ Revised.

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

2/ Data for sheet and strip, plate, extrusions (other than tubing), pipe and tubing, and other have been combined to avoid disclosing company proprietary data.

TABLE 4 CAPACITIES OF U.S. TITANIUM DIOXIDE PIGMENT PLANTS ON DECEMBER 31, 1998 1/ 2/

		Ye	Yearend capactiy		
		(met	ric tons per ye	ar)	
		Sulfate	Chloride		
Company	Plant location	process	process	Total	
E.I. du Pont de Nemours & Co. Inc.	De Lisle, MS		280,000	280,000	
	Edgemoor, DE		145,000	145,000	
	New Johnsonville, TN		330,000	330,000	
Kemira Pigments	Savannah, GA	54,000	91,000	145,000	
Kerr-McGee Chemical Corp.	Hamilton, MS		160,000	160,000	
Louisiana Pigment Co. LP	Lake Charles, LA		110,000	110,000	
Millennium Inorganic Chemicals Inc.	Ashtabula, OH		190,000	190,000	
-	Baltimore, MD	44,000	51,000	95,000	
Total		98,000	1,357,000	1,455,000	

1/ Operating capacity based on 7-day-per-week full production.

2/ Table does not include Hitox Corp.'s Corpus Christi, TX, production capacity of about 16,400 tons per year of buff TiO2 pigments that is produced by refining and fine grinding of synthetic rutile.

TABLE 5 COMPONENTS OF U.S. TITANIUM DIOXIDE PIGMENT SUPPLY AND DEMAND 1/

(Metric tons unless otherwise specified)

		1997		1998	
		Gross	TiO2	Gross	TiO2
		Weight	content	Weight	content
Production 2/		1,340,000	1,260,000 e/	1,330,000	1,280,000
Shipments: 3/					
Quantity		1,360,000	1,270,000 r/	1,380,000	1,320,000
Value	thousands	\$2,400,000	2,400,000	\$2,540,000	\$2,540,000
Exports		405,000	381,000	398,000	384,000 e/
Imports for consumption		194,000	183,000 e/	200,000	192,000 e/
Stocks, yearend		107,000 r/	101,000 r/ e/	96,900	93,300 e/
Consumption, apparent 4/		1,130,000	1,060,000 r/ e/	1,140,000	1,090,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Excludes production of buff pigment.

3/ Includes interplant transfers.

4/ Production plus imports minus exports plus stock decrease or minus stock increase.

Source: Bureau of the Census and U.S. Geological Survey.

TABLE 6 U.S. CONSUMPTION OF TITANIUM CONCENTRATES IN 1998 1/

(Metric tons)

weight	content
0	
1,290,000	NA
14,000	NA
1,300,000	980,000
384,000	NA
37,300	NA
421,000	392,000
1,670,000	NA
51,300	NA
1,730,000	1,370,000
	$\begin{array}{c c} & 14,000 \\ \hline 1,300,000 \\ \hline 384,000 \\ 37,300 \\ \hline 421,000 \\ \hline 1,670,000 \\ 51,300 \\ \hline \end{array}$

NA Not available.

 $1/\operatorname{Data}$ are rounded to three significant digits; may not add to totals shown.

2/ Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

3/ Excludes ilmenite used to produce synthetic rutile.

4/ Includes alloys, carbide, welding-rod coatings and fluxes, ceramics, chemicals, glass fibers, and titanium metal.

TABLE 7U.S. CONSUMPTION OF TITANIUM PRODUCTSIN STEEL AND OTHER ALLOYS 1/ 2/

(Metric tons)

	1997	1998
Carbon steel	3,540 r/	3,630
Stainless and heat-resisting steel	1,510	1,410
Other alloy steel (includes HSLA)	149 r/	126
Tool steel	W	W
Total steel	5,200 r/	5,170
Cast irons	W	W
Superalloys	1,780 r/	837
Alloys, other than above	491 r/	428
Miscellaneous and unspecified	48 r/	50
Total consumption	7,520 r/	6,480

r/ Revised. W Withheld to avoid disclosing company proprietary data; included with "Miscellaneous and unspecified."

Includes ferrotitanium, titanium scrap, and other titanium additives.
 Data are rounded to three significant digits; may not add to totals shown.

TABLE 8U.S. DISTRIBUTION OF DOMESTIC TITANIUM PIGMENTSHIPMENTS, TITANIUM DIOXIDE CONTENT, BY INDUSTRY 1/

(Percentage)

Industry	1997	1998
Ceramics	W	W
Coated fabrics and textiles	W	0.2
Floor coverings	0.9	W
Paint, varnish, lacquer	49.8	51.2
Paper	23.3	17.6
Plastics	18.0	19.5
Printing ink	0.5	2.7
Roofing granules	W	W
Rubber	1.6	1.9
Other 2/	5.9	6.9
Total	100.0	100.0

W Withheld to avoid disclosing company proprietary data; included with "Other."

1/ Excludes exports.

2/ Includes agricultural, building-materials, cosmetic, food industries and industries with data represented by "W." Also includes shipments to distributors.

TABLE 9 U.S. STOCKS OF TITANIUM MINERAL CONCENTRATES AND PIGMENT, DECEMBER 31 1/

(Metric tons)

	1997		199	98
	Gross	TiO2	Gross	TiO2
	weight	content	weight	content
Concentrates: 2/				
Ilmenite and titanium slag	330,000	234000	380,000	270,000
Rutile, natural and synthetic	64,600	59100	121,000	111,000
Titanium pigment 3/	107,000 r/	101000 r/e/	96,900	91,100 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to three significant digits.

2/ Consumer stocks.

3/ Data from Bureau of the Census. Producer stocks only.

TABLE 10
PUBLISHED PRICES OF TITANIUM CONCENTRATES AND PRODUCTS

		1997	1998
Concentrates:			
Ilmenite, f.o.b. Australian ports	per metric ton	\$68.00-\$81.00	\$72.00-\$77.00
Rutile, bagged, f.o.b. Australian ports	do.	650.00-710.00	570.00-620.00
Rutile, bulk, f.o.b. Australian ports	do.	500.00-550.00	470.00-530.00
Titanium slag, 80% TiO2 Canada 1/	do.	309.00	340.00
Titanium slag, 85% TiO2 South Africa 1/	do.	391.00	386.00
Metal:			
Sponge	per pound	4.25-4.50	4.25-4.50
Ferrotitanium	do.	1.98-2.08	1.25-1.35
Scrap, turnings, unprocessed	do.	0.70-0.73	0.30-0.40
Pigment:			
Titanium dioxide pigment, f.o.b. U.S. plants, anatase	do.	1.01-1.03	0.96-0.98
Titanium dioxide pigment, f.o.b. U.S. plants, rutile	do.	1.04-1.06	0.97-0.99
1/Unit value based on U.S. imports for consumption			

1/ Unit value based on U.S. imports for consumption.

Sources: American Metal Market, Chemical Market Reporter, Industrial Minerals (London), Metal Bulletin, Platt's Metals Week, and industry contacts.

	19	1997		8
	Quantity	Value	Quantity	Value
Class	(metric tons)	(thousands)	(metric tons)	(thousands)
Metal:				
Sponge	976	\$3,980	348	\$1,860
Scrap	5,500	12,900	7,010	14,100
Other unwrought:				
Billet	666	17,000	543	18,900
Blooms and sheet bars	3,030	70,200	2,010	50,700
Ingot	613	10,800	528	9,350
Other	429	12,700	791	14,400
Wrought:				
Bars and rods	1,340	61,000	2,010	69,600
Other	3,860	208,000	3,780	213,000
Total	16,400	396,000	17,000	392,000
Ores and concentrates	23,800	11,400	59,700	5,180
Pigment and oxides:				
Titanium dioxide pigments	362,000	510,000	356,000	563,000
Titanium oxides	42,800	66,500	42,200	69,900
Total	405,000	576,000	398,000	633,000

TABLE 11 U.S. EXPORTS OF TITANIUM PRODUCTS, BY CLASS 1/

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

TABLE 12 U.S. IMPORTS FOR CONSUMPTION OF TITANIUM CONCENTRATES, BY COUNTRY 1/

	1997	1997		1998	
	Quantity	Value	Quantity	Value	
Concentrate and country	(metric tons)	(thousands)	(metric tons)	(thousands)	
Ilmenite:					
Australia	438,000	\$31,200	277,000	\$18,300	
India	56,300	3,850	50,000	4,030	
Ukraine	27,100	2,200	52,100	4,450	
Total	522,000	37,200	379,000	26,800	
Titanium slag:					
Canada	49,700	15,400	103,000	38,600	
Norway			41,000	14,300	
South Africa	380,000	153,000	481,000	186,000	
Other	41	34	832	268	
Total	430,000	168,000	626,000	239,000	
Rutile, natural:					
Australia	48,600	23,400	84,500	36,100	
Austria			5,020	2,760	
Canada	31	46	5,270	2,700	
South Africa	134,000	56,100	141,000	60,700	
Ukrainie			10,000	4,020	
Other	42 r/	127 r/	22	232	
Total	183,000	79,600	246,000	106,000	
Rutile, synthetic:					
Australia	141,000	56,700	126,000	40,200	
India			9,850	4,680	
Malaysia	6,920	4,080	4,220	4,390	
Ukraine	5,080	4,220	234	82	
Other	1	11	23	3	
Total	153,000	65,000	141,000	49,300	
Titaniferous iron ore: Canada 2/	43,900	7,960	24,000	2,850	

r/ Revised.

 $1/\operatorname{Data}$ are rounded to three significant digits; may not add to totals shown.

2/ Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregate and steel furnace flux.

TABLE 13

U.S. IMPORTS FOR CONSUMPTION OF TITANIUM METAL, BY CLASS AND COUNTRY 1/

	1997		1998	
	Quantity	Value	Quantity	Value
Class and country	(metric tons)	(thousands)	(metric tons)	(thousands)
Unwrought:				
Sponge:				
China	413	\$3,200	62	\$536
Japan	6,370	56,900	2,660	25,300
Kazakhstan	1,150	7,930	767	5,660
Russia	7,650	49,400	7,360	50,800
United Kingdom	507	3,890	30	191
Other	51	364	34	246
Total	16,100	122,000	10,900	82,800
Waste and scrap:				
Canada	262	640	204	489
France	1,160	6,130	1,210	4,770
Germany	478	2,590	232	941
Japan	1,970	7,340	2,590	9,490
Russia	1,920	10,900	1,040	6,010
United Kingdom	2,560	12,600	2,440	6,840
Other	2,300 r/	8,800 r/	2,050	6,070
Total	10,700	49,100	9,770	34,600
Ingot and billets:				
China	381	3,960	348	3,210
Russia	3,890	69,700	1,630	30,000
United Kingdom	1,070	16,200	143	2,570
Other	76 r/	1,620	118	1,660
Total	5,410	91,500	2,240	37,400
Powder	244	2,840	147	1,590
Other: 2/				
Japan	1	25	137	2,150
Russia	45 r/	287 r/	3	26
Other	108 r/	1,270 r/	176	2,800
Total	154 r/	1,580 r/	316	4,980
Wrought products and castings: 3/				
Japan	500	17,900	755	21,400
Russia	3,390	36,000	2,360	33,700
United Kingdom	356 r/	13,100 r/	268	12,800
Other		13,100 r/	510	21,800
Total	4,590 r/	80,100 r/	3,900	89,700
/D : 1			· · ·	,

r/ Revised.

 $1/\operatorname{Data}$ are rounded to three significant digits; may not add to totals shown.

2/ Includes blooms, sheet, bars, slabs, and other unwrought.

3/ Includes bars, castings, foil, pipes, plates, profiles, rods, sheet, strip, tubes, wire, and other.

TABLE 14 U.S. IMPORTS FOR CONSUMPTION OF TITANIUM PIGMENTS, BY COUNTRY 1/

	1997		1998		
	Quantity	Value	Quantity	Value	
Country	(metric tons)	(thousands)	(metric tons)	(thousands	
80% or more titanium dioxide:					
Australia	3,710	\$5,700	2,730	\$5,730	
Belgium	1,320	1,950	3,280	5,850	
Canada	74,200	116,000	74,000	124,000	
China	2,100	2,530	2,960	3,540	
Finland	731	1,500	1,070	2,420	
France	2,740	5,170	5,010	7,670	
Germany	26,400	50,200	26,900	52,500	
Italy	101	151	896	1,330	
Japan	7,190	15,500	7,260	18,300	
Norway	6,220	9,050	9,760	15,500	
Poland	1,190	1,760	500	869	
Singapore	3,300	5,110	3,650	6,250	
Slovenia	2,340	3,670	2,780	4,350	
South Africa	244	373	3,170	5,350	
Spain			4,860	6,950	
United Kingdom	263	469	145	260	
Other	1,570 r/	2,500 r/	2,900	4,660	
Total	134,000	221,000	152,000	266,000	
Other titanium dioxide:					
Canada	2,090	3,460	2,100	3,570	
France	6,800	10,600	4,400	6,900	
Germany	1,070	10,600	745	6,330	
Italy	2,090	3,870	1,640	2,820	
South Africa	7,550	10,800	4,510	7,300	
Spain	14,000	22,300	4,550	7,830	
United Kingdom	3,020	7,360	2,210	6,110	
Other	2,670	8,130	1,940	4,050	
Total	39,300	77,000	22,100	44,900	
Titanium oxide:					
Australia			2,400	4,320	
Belgium	2,190	3,300	2,620	3,840	
Canada	84	142	297	465	
China	1,530	1,580	2,560	2,910	
Czech Republic	1,560	2,400	1,550	2,700	
France	10,200	13,100	10,100	13,400	
Germany	2,560	4,680	1,520	3,330	
Other	3,190	10,700	4,740	12,200	
Total	21,400	35,900	25,800	43,100	
Grand total	194,000	334,000	200,000	354,000	

r/ Revised.

 $1/\operatorname{Data}$ are rounded to three significant digits; may not add to totals shown.

TABLE 15 TITANIUM: WORLD PRODUCTION OF CONCENTRATES (ILMENITE, LEUCOXENE, RUTILE, AND TITANIFEROUS SLAG), BY COUNTRY 1/ 2/

(Metric tons)

Concentrate type and country	1994	1995	1996	1997	1998 e/
Ilmenite and leucoxene: 3/					
Australia:					
Ilmenite	1,782,000	1,980,000	2,028,000	2,233,000	2,379,000 4/
Leucoxene	35,000	31,000	33,000	32,000	28,000 4/
Brazil 5/	97,439	102,125	97,955	97,174 r/	97,500
China e/	155,000	160,000	165,000	170,000	175,000
India e/	290,000 r/	290,000 r/	330,000 r/	300,000	300,000
Malaysia	116,696	151,680	244,642	167,504	126,000
Norway	826,391	833,238	746,583	750,000 e/	590,000
Portugal e/	20				
Sierra Leone e/	47,400 4/				
Sri Lanka	60,445	49,655	62,810	18,970	20,000
Thailand	1,677	33			
Ukraine e/	530,000	359,000 4/	250,000	250,000	250,000
United States	W	W	W	W	601,000 6/
Vietnam e/	32,000	50,000	50,000	50,000	80,000
Total	3,970,000 r/	4,010,000 r/	4,010,000 r/	4,070,000 r/	4,650,000
Rutile:					
Australia	233,000	195,000	180,000	235,000	237,000 4/
Brazil	1,911	1,985	2,018	1,742 r/	1,750
India e/	13,000 r/	14,000	15,000 r/	14,000 r/	14,000
Sierra Leone e/	137,000 4/				
South Africa e/	78,000	90,000	115,000	123,000 r/	120,000
Sri Lanka	2,410	2,697	3,532	2,970	3,000
Thailand	49				
Ukraine e/	80,000	112,000 4/	50,000	50,000	50,000
United States	W	W	W	W	(7/)
Total	545,000 r/	416,000	366,000 r/	427,000 r/	426,000
Titaniferous slag: 8/					
Canada e/	764,000 4/	815,000	825,000	850,000	950,000
South Africa e/	744,000	990,000	1,000,000	1,100,000 r/	1,100,000
Total	1,510,000	1,810,000	1,830,000	1,950,000 r/	2,050,000

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

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

2/ Table includes data available through August 5, 1999.

3/ Ilmenite is also produced in Canada and South Africa, but this output is not included here because an estimated 90% of it is duplicative of output reported under "Titaniferous slag," and the rest is used for purposes other than production of titanium commodities, principally steel furnace flux and heavy aggregate.

4/ Reported figure.

5/ Excludes production of unbeneficiated anatase ore.

6/ Includes synthetic rutile and rutile.

7/ Included with "Ilmenite and leucoxene."

8/ Slag is also produced in Norway, but this output is not included under "Titaniferous slag" to avoid duplicative reporting.