TITANIUM

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Titanium is present in most rocks and soil and is the ninth most abundant element in the Earth's crust. In nature, titanium is not found in its metallic form but occurs in many mineral forms such as oxides, titanates, and silicotitanates. The titanium-bearing minerals that have significant economic importance include ilmenite, leucoxene, and rutile.

Approximately 95% of titanium is consumed as titanium dioxide (TiO_2), a white pigment in paints, paper, and plastics. The superiority of TiO_2 as a white pigment is attributable to its high refractive index and resulting light-scattering ability. Consequently, TiO_2 pigment provides high opacity and brightness. Titanium metal alloys are used in aerospace and other industries for their high strength-to-weight ratio and corrosion resistance.

In 1999, global production of titanium minerals and pigment was not significantly different compared with that of 1998. There were, however, important changes in the ownership of titanium mineral and pigment corporations. The titanium mineral industry saw a major consolidation of ownership among the top producers. Meanwhile, in the TiO_2 pigment industry, a newcomer to the industry acquired a predominant interest in a major producer. Because of decreased demand from the commercial aerospace industry, production of titanium metal decreased markedly in 1999 compared with that of 1998.

Legislation and Government Programs

The Defense National Stockpile Center continued to solicit offers for the sale of titanium sponge held in the Government stockpile. For fiscal year 2000, 4,540 metric tons (t) of titanium sponge was being offered for sale. In accordance with section 3305 of the National Defense Authorization Act for fiscal year 1996 (Public Law 104-106), 250 t of titanium sponge was transferred to the Army's Tank and Automotive Command for use in the weight-reduction portion of the main battle tank upgrade program. Fiscal year 1999 was the fourth year of this program, which provides for annual transfers of up to 250 t of titanium sponge to continue through fiscal year 2003. 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, 13). Fiscal year 1999 disposals from the stockpile totaled 392 t. At yearend 1999, the National Defense Stockpile held 31,200 t of titanium sponge.

Production

Mineral Concentrates.—Commercial forms of titanium mineral concentrates include ilmenite, leucoxene, rutile, slag, and synthetic rutile. Mining of titanium minerals is usually performed using surface methods. A dredge is often used for the recovery of titanium-mineral placer deposits. Gravity spirals are used for wet separation of suite of heavy minerals (HM), while magnetic and high-tension separation circuits are used to separate the HM constituents. In some cases, ilmenite is further beneficiated to produce synthetic rutile or titaniferous slag. Although numerous technologies are used to produce synthetic rutile, nearly all are based on either selective leaching or thermal reduction of iron and other impurities in ilmenite. Titaniferous slag, with a TiO_2 content of up to 95%, is produced using an energy-intensive pyrometallurgical process.

In 1999, Australia, Canada, India, Norway, and South Africa led the world's production of titanium mineral concentrate. U.S. mineral concentrate producers included E.I. du Pont de Nemours & Co. Inc. (DuPont), Kerr-McGee Chemical Corp., and Iluka Resources Inc. (a subsidiary of Iluka Resources Ltd.). DuPont's Trail Ridge mining operations in Starke, FL, produced a mixed product containing ilmenite, leucoxene, and rutile that was used as a feedstock in DuPont's TiO_2 pigment operations. Iluka's mining operations in Green Cove Springs, FL, and Stony Creek, VA, produced both rutile and ilmenite concentrates. 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. announced plans to proceed with final feasibility work at its titanium/zircon deposit in Camden, TN. The final feasibility work involves the design, construction and operation of a pilot facility, additional drilling, development of a detailed mine plan, product marketing, and strategic alliances. Titanium and zircon are contained in sand deposits that are estimated to total 540 million metric tons (Mt) averaging 3.6% HM. Altair was also in the final development stages of commercializing its centrifugal jig, which recovers extremely fine, heavy particulate matter using a combination of a mechanical jig and centrifugal force (Altair International, 1999).

Iluka Resources Ltd. announced plans to conduct a detailed feasibility study into proposals for a $100-million expansion of the company's operations in the United States. The expansion involves a 70% increase in production capacity. If development plans are confirmed by the feasibility study, construction would begin late in 2000. The complete expansion to increase annual production by 220,000 t of mineral product would be implemented in stages over 4 or 5 years (Iluka Resources Ltd., 1999).

Metal.—Titanium sponge is the rudimentary form of

titanium metal. The initial production step involves the chlorination of titanium-containing mineral feedstocks to produce titanium tetrachloride ($TiCl_4$). The next step is usually based on the Kroll process where $TiCl_4$ is reduced with magnesium to form titanium sponge. In 1999, titanium sponge was produced in China, Japan, Kazakhstan, Russia, Ukraine, and the United States. U.S. producers of titanium sponge included The Alta Group, Allegheny Technologies Inc., and Titanium Metals Corp. Domestic operating capacity of titanium sponge was estimated to be 21,600 metric tons per year (t/yr) (table 2). Data on domestic production of titanium sponge have not been published in order to avoid disclosing company proprietary data.

Titanium ingot is produced by the 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 commercial melting methods used to produce ingot. In 1999, 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 five companies in nine locations. U.S. production of ingot decreased by about 23% compared with that of 1998 (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 billet, pipe and tube, plate, rod and bar, sheet and strip, wire, 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 1999, U.S. production of mill products decreased by 27% compared with that of 1998.

Titanium castings are commonly produced by two techniques: investment casting and rammed graphite mold casting. In 1999, U.S. producers of titanium castings included Coastcast Corp., Flowserve Corp., Howmet Corp., Precision Cast Parts Corp., Reactive Alloy Manufacturing Inc., RTI International Metals Inc., Selmet Inc., Titanium Industries Inc., Wah Chang Co., and Wyman-Gordon Titanium Castings LLC.

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

In 1999, Alta Group, a 340-t/yr-Hunter-route sponge producer and supplier of high-purity titanium to the semiconductor industry, became a part of Honeywell International Inc. In August, Alta Group was initially acquired by AlliedSignal Inc. through the acquisition of Alta Group's parent division, Johnson Matthey Electronics. In December, however, AlliedSignal merged with Honeywell Inc. to form Honeywell International Inc. Alta Group is now a part of Honeywell's Wafer Fabrication Materials (AlliedSignal Inc., 1999; Honeywell International Inc., 1999).

TiO_2 Pigment.—TiO_2 pigment is produced using either the chloride process or the sulfate process. In the sulfate process, ilmenite or titanium slag is reacted with sulfuric acid. Titanium hydroxide is precipitated by hydrolysis, filtered, and calcined. In the chloride process, rutile is converted to $TiCl_4$ by chlorination in the presence of petroleum coke. $TiCl_4$ is oxidized with air or oxygen at about 1,000° C, and the resulting fine-size TiO_2 is calcined 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.

Although either process may be used to produce pigment, 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 finishing operations, 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 compounds.

TiO_2 pigment produced by either process is typed by crystal form, either anatase or rutile. 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 TiO_2 pigment is produced and subsequently finished, TiO_2 pigment can exhibit a range of functional properties, including opacity, durability, dispersion, and tinting.

U.S. producers of TiO_2 pigment were DuPont, Kemira Inc., Kerr-McGee, Louisiana Pigment Co. LP, and Millennium Inorganic Chemicals Inc. (table 4). Domestic production of TiO_2 pigment in 1999 increased 2% compared with that of 1998 (table 5). Capacity utilization for the domestic pigment industry was about 89%.

Huntsman Inc., a privately held company and an outsider to the titanium industry, acquired Imperial Chemical Industries plc.'s (ICI) global Tioxide Group TiO_2 pigment operations. In 1999, Tioxide operated TiO_2 pigment facilities in eight countries with a total production capacity of 517,000 t/yr. Under the terms of the acquisition, Huntsman would control 70% of a new company called Huntsman ICI Holdings LLC, with the remaining interest still controlled by ICI. Previously, DuPont had agreed to acquire most of the TiO_2 pigment assets from ICI, however, the plans were withdrawn in February 1999 when acceptable terms could not be reached with the U.S. Federal Trade Commission (Industrial Minerals, 1999c).

Kemira Pigments Oy initiated a $20 million efficiency improvement program at its TiO_2 pigment plant in Savannah, GA. The program was scheduled to be completed by yearend 2000 and was expected to improve process control systems and operational efficiencies (Kemira Pigments Oy, 1999).

Kerr-McGee completed a $53-million expansion at its Hamilton, MS, TiO_2 pigment plant, bringing capacity to 188,000 t/yr. According to the company, the implementation of cost-reduction programs at Hamilton has resulted in savings of more than $100 per metric ton versus yearend 1998 levels (Kerr-McGee Corp., 2000).

Consumption

Mineral Concentrates.—On a content basis, domestic consumption of titanium minerals concentrates was 1.4 Mt, nearly unchanged compared with that of 1998. Consumption of ilmenite and slag decreased 2%, while consumption of rutile and synthetic rutile increased 5%. On a gross weight basis, about 98% of the domestic consumption of titanium mineral concentrates was used to produce TiO_2 pigment.

Consumption data for titanium concentrates are developed by the U.S. Geological Survey from one voluntary survey of domestic operations. Of the 18 operations canvassed, 11 responded, representing 64% of the data in table 6. Data for nonrespondents were estimated on the basis of prior-year consumption with some adjustments for present-year trends (table 6).

Metal.—Decreased demand from the commercial aircraft industry resulted in decreased consumption of titanium metal products. Overall consumption of titanium sponge and scrap decreased by about 30% compared with that of 1998. Scrap consumption decreased by about 23% compared with that of 1998, while sponge consumption decreased by about 36%. Scrap supplied a calculated 55% of ingot feedstock, a 9% increase compared with that of 1998. Falling demand for titanium mill products by the commercial aerospace and nonaerospace markets resulted in a decrease in ingot consumption and an 21% decrease in net shipments of mill products. Reported shipments of titanium castings decreased by 17%. Estimated U.S. mill product usage by application was as follows: aerospace, 60% and nonaerospace uses, 40%. 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 increased by 16% compared with revised data for 1998 (tables 3 and 7).

TiO_2 Pigment.—The three largest end uses of TiO_2 pigment were paint and coatings, paper, and plastics (table 8). Other consuming industries included ceramics, fabrics and textiles, floor coverings, printing ink, and rubber. In 1999, apparent domestic consumption of TiO_2 pigment was about 1.2 Mt, a 2% increase compared with that of 1998 (table 5).

In the paint and coatings industry, TiO_2 pigment is used in white and color formulations. The industry is largely made up of equipment, architectural, and special-purpose applications. Equipment applications typically require high brightness, gloss, and durability, as well as resistance to abrasion, heat, and chemical attack. Architectural applications require high durability, color brightness, and hiding power. Special-purpose coatings include marine, traffic, refinish, and aerosol coatings. The TiO_2 content for paint and coatings varies significantly.

The plastics industry primarily consumes rutile-grade pigment. TiO_2 pigment is used in a variety of plastics applications. Primarily, TiO_2 pigment provides opacity and acts as barrier against ultraviolet light degradation. TiO_2 pigment is often introduced as pelletized concentrate containing up to 50% by weight TiO_2 in a carrier resin, however, liquid and dry concentrates also are used by the industry. The TiO_2 content for plastics normally ranges from 3% to 25% by weight of the finished product.

TiO_2 pigment in paper products provide opacity and brightness. The paper industry consumes TiO_2 pigment as filler and in coatings. Paper products contain a high percentage of non-TiO_2 base minerals as filler material with the typical TiO_2 content less than 5% of the dry weight of paper. Anatase-grade pigment is preferred in the paper industry because it is less abrasive to papermaking machinery.

Stocks

On a gross weight basis, yearend consumer inventories of titanium mineral concentrates increased by 19% compared with those of 1998 (table 9). Meanwhile, producer stocks of TiO_2 pigment were about 137,000 t, a 41% increase from those of 1998. Compared with those of 1998, industry stocks of titanium sponge and scrap fell by 25% and 30%, respectively. Owing largely to decreased consumption by mill product producers, forgers, and fabricators, stocks of titanium ingot increased by 28% compared with those of 1998.

Prices

In 1999, prices of titanium mineral concentrates reflected an increased demand for chloride-grade slag. The yearend published price range for bulk rutile concentrates was $435 to $510 per metric ton, a decrease of 6% compared with that of 1998. Meanwhile, the price range for bagged rutile concentrates commonly used in the welding rod coatings industry was $500 to $530 per metric ton, a decrease of 13% compared with that of 1998. Ilmenite prices were significantly higher in 1999 compared with those of 1998, with a yearend range of $90 to $103 per metric ton. 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 15%, while prices for South African slag increased 5% compared with those of 1998 (table 10).

Pricing trends for anatase- and rutile-grade pigment were mixed. Although demand for anatase-grade pigment, generally used in the paper industry, was believed to be higher, the yearend published price decreased 4% compared with that of 1998. Meanwhile, the yearend price for rutile-grade pigment was $0.99 to $1.02 per metric ton, a 3% increase compared with that of 1998 (Chemical Market Reporter, 1999).

Demand for ferrotitanium and titanium scrap by the steel industry combined with the decreased generation of scrap by titanium metal industry resulted in significantly higher prices for scrap and ferrotitanium. The averaged yearend prices for ferrotitanium and unprocessed scrap turnings increased 77% and 214% compared with those of 1998.

Foreign Trade

Mineral Concentrates.—As has been the case for some time, 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 391,000 t; 225,000 t; 678,000 t; and 119,000 t, respectively (table 12). On a TiO_2 content basis, imports of mineral concentrates were estimated to be nearly unchanged compared with those of 1998. Exports of titanium mineral concentrates were 9,380 t, a significant decrease compared with 59,700 t in 1998 (table 11).

Metal.—U.S. import reliance extends 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 metal industry. Owing to decreased demand for commercial aircraft, sponge imports decreased by 45% compared with those of 1998. The leading import sources of titanium sponge were Japan, Kazakhstan, and Russia. The leading import sources of titanium waste and scrap were France, Japan, and the United Kingdom (table 13).

TiO_2 Pigment.—Although the United States was a net exporter of TiO_2 pigment, a significant quantity of TiO_2 pigment was imported. During 1999, TiO_2 pigment imports increased by 13%, and the leading import sources of titanium pigment were Canada, France, Germany, Japan, and Spain. Compared with those of 1998, imports of titanium pigment containing more than 80% TiO_2 totaled 190,000 t, a 25% increase; other titanium pigment, 9,320 t, a 58% decrease, and titanium oxide, 25,700 t, nearly unchanged (table 14). Exports of TiO_2 pigment were 344,000 t, nearly unchanged compared with those of 1998. Exports of titanium oxide (unfinished pigment) were 39,000 t, a 7% decrease compared with those of 1998.

World Review

In 1999, Australia, Canada, India, Norway, and South Africa continued to lead the world's production of titanium mineral concentrates (table 15). Production of slag was nearly unchanged compared with that of 1998. Owing largely to decreased production by Australian producers, world production of ilmenite and natural rutile, excluding the United States, was estimated to have decreased 9% and 12%, respectively, compared with that of 1998.

Australia.—In a significant restructuring of the mineral concentrate industry, Westralian Sands Ltd. and RGC Ltd., two Australian producers of titanium minerals, merged to form Iluka Resources. The merger was estimated to represent 32% of the world's capacity to produce titanium minerals. Operational changes for Iluka Resources included an idling of its mine and synthetic rutile plant at South Capel, Western Australia; however, Iluka Resources continued to operate its nearby Yoganup, Yoganup Extended, and Busselton mines and its North Capel synthetic rutile plant. Iluka Resources' exploration efforts were ongoing along the Swan coastal plain, Western Australia, and in the Murray Basin, Victoria (Iluka Resources Ltd., 2000, p. 4).

In April, owing to operational difficulties, Broken Hill Proprietary Co. Ltd. (BHP) closed its Beenup operation in Western Australia (Broken Hill Proprietary Co. Ltd., 1999, p. 18). Prior to the closure, Beenup was considered to be a major new source of ilmenite with a design capacity of 600,000 t/yr. Operational difficulties were caused by excessive clay in the process tailings (Broken Hill Proprietary Co. Ltd., 1998, p. 9).

Consolidated Rutile Ltd. (CRL) moved its dredging operations from its depleted Gordon deposit to its Yarraman deposit on North Stradbroke Island, New South Wales. Throughout 1999, CRL's Ibis mine and Pinkenba separation plant continued to operate. In 1999, CRL produced 57,400 t of rutile and 74,000 t of ilmenite (Iluka Resources Ltd., 2000, p. 13).

Monto Minerals NL continued development at its Goondicum deposit in southeastern Queensland. At yearend, the company was conducting a final feasibility study. If the project comes to fruition, Monto expects to produce 275,000 t/yr of a 50%-grade ilmenite and 100,000 t/yr of a titano-magnetite concentrate. The deposit is reported to contain a 46-Mt resource averaging 4.6% to 4.9% ilmenite; however, further drilling in the southern and eastern portion of the deposit may add to the measured resource (Minerals Gazette, 1999a).

The Murray Basin Joint Venture (MBJV) continued its exploration program covering in the Murray Basin. In 1999, an inferred resource of 230 Mt at 2.6% HM was estimated for the Ginkgo deposit in the South Pooncarie area. BeMaX Resources NL is the operator of the MBJV and holds a 50% interest. The remaining partners included Imperial Mining (Australia) NL (25%) and Probo Mining Pty Ltd. (25%) (Stephen Everett, Managing Director, BeMaX Resources NL, Quarterly report for the period ended 31 December 1999, accessed September 1, 2000, at URL http://www.bemax.com.au/Dec99quarter.html).

Murray Basin Minerals NL, a subsidiary of Craton Resources NL, increased its estimate of the HM resource at its Mindaria-Mercunda project in the Murray Basin, Western Victoria. According to the company, the resource base is now believed to be 22.2 Mt averaging 3% HM (Minerals Gazette, 1999b).

Canada.—In 1999, fire damaged two of nine furnaces at QIT fer et Titane's slag operation near Sorel, Quebec. Production was interrupted for some time. Production output reported by Rio Tinto plc. (100% interest in QIT and 50% interest in South African producer Richards Bay Minerals) decreased 7% compared with that of 1998 (Rio Tinto plc., 2000, p. 8, 40). QIT's operations in Canada included its slagging operation at Sorel and mining operation in Lac Allard, Quebec.

Preliminary drilling and metallurgical testing were underway at NAR Resources Ltd.'s and Titanium Corp. of Canada Ltd.'s heavy mineral sands deposit near Truro, Nova Scotia. In the unprocessed bulk sample, 92% of the HM were contained in the size fraction between 100 and 200 mesh. In gravity tests, between 88% and 92% of the titanium was recovered in a concentrate assaying between 10.8% and 13.5% TiO_2. Further drilling and testing were anticipated to improve on preliminary results (NAR Resources Ltd., 1999).

Finland.—Though a process improvement program, capacity at Kemira Oy's Pori TiO_2 pigment operation was raised to 120,000 t/yr, a 20,000-t/yr increase. Capacity of ultraviolet specialty product grades was increased in 1999 and was expected to be increased further in 2000. Specific details, however, were not available (Kemira Oy, 2000, p. 52).

Germany.—Sachtleben GmbH increased TiO_2 pigment

capacity at its Duisberg, Germany, sulfate-route plant to 100,000 t/yr. The 20,000-t/yr increase was achieved through process improvements. In 1999, Sachtleben was a major supplier of anatase-grade pigment used to deluster synthetic fibers (Industrial Minerals, 1999e).

India.—Austpac Resources NL and Indian Rare Earths Ltd. (IREL) formed a joint venture to build and operate a 10,000-t/yr synthetic rutile plant. The new plant was expected to be incorporated in IREL's Orissa facility near Chatrapur, using technology based on Austpac's enhanced roasting magnetic separation process and enhanced acid regeneration system. Production is scheduled to begin by 2001 (Industrial Minerals, 1999a).

Kazakhstan.—Feasibility studies have been completed at the Satpayevskaoye ilmenite deposit, a part of the Bekhtimir mining project. A 115,000-t/yr mine operation has been proposed to produce a 55%-TiO_2-content ilmenite. Most of the production would be for use by the Ust Kamenogorsk Titanium and Magnesium Metal Plant, however, some production material could be used to produce TiO_2 pigment. Two additional deposits at Bekhtimir were under prefeasibility evaluation (Industrial Minerals, 1999b).

Kenya.—Tiomin Resources Inc. has identified a total of four titanium-bearing deposits in the coastal region of Kenya. In 1999, a feasibility study was underway at the Kwale mineral sands deposit near Mombasa. Tiomin has proposed mining and processing operations at Kwale expected to last at least 14 years. In the initial phase of development, the operation would produce 300,000 t/yr of ilmenite and 70,000 t/yr of rutile (Tiomin Resources Inc., 2000, p. 2, 10).

Mozambique.—In April, BHP announced its intention to withdraw from the Mozambique Titanium Joint Venture with Kenmare Resources plc. The joint venture had established a resource of 36 Mt of ilmenite at the Moma-Congolone deposit. In 1999, a prefeasibility study was being performed by Minproc Ltd. A full feasibility study was scheduled for completion in 2000 (Kenmare Resources plc., 1999a, b).

In southern Mozambique near Chibuto, a prefeasibility study was being conducted at Southern Mining Corp.'s Corridor Sands deposit. Initial drilling established a resource of 974 Mt averaging 8.5% HM (TZ Minerals International Pty. Ltd., 1999).

Sri Lanka.—In the northwest region of Sri Lanka, Iluka Resources was examining an ilmenite deposit near Putalam. According to a preliminary resource assessment, the deposit held a resource of 7.38 Mt of HM (Iluka Resources Ltd., 2000, p. 16).

Ukraine.—Government-owned Krym Titan planned to increase the operating capacity at its Armyansk TiO_2 pigment plant to as high as 60,000 t/yr. The process improvements were being financed by ITA GmbH, a Vienna-based trading company. The Armyansk plant was commissioned in the 1970's with a production capacity of 80,000 t/yr. In 1998, however, operating capacity was limited to about 30,000 t (Industrial Minerals, 1999d).

United Kingdom.—Millennium completed a 41,000-t/yr expansion at its Stallingborough TiO_2 pigment facility. Capacity at the chloride-route facility was increased to 150,000 t/yr (Millennium Inorganic Chemicals Inc., 2000).

Outlook

The future outlook for TiO_2 pigment industry is expected to include a continued consolidation of ownership, expansion by the chloride-route TiO_2 pigment capacity in lieu of the sulfate-route capacity and increased demand for higher TiO_2 content mineral feedstocks (synthetic rutile and slag). Over the next 5 years, global economic growth is expected to increase TiO_2 pigment consumption by 2% to 3% annually. Since approximately 95% of titanium minerals are consumed to produce TiO_2 pigment, consumption of titanium minerals also is expected to increase 2% to 3% annually. In the titanium metal industry, a growing world economy together with increased airline traffic are expected to end the recent fall in consumption of titanium metal and lead to increased consumption by more than 5% annually during the next decade.

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TABLE 1
SALIENT TITANIUM STATISTICS 1/

(Metric tons, unless otherwise specified)

	1995	1996	1997	1998	1999
United States:					
Ilmenite and titanium slag:					
Imports for consumption	861,000	939,000	952,000	1,010,000	1,070,000
Consumption	1,410,000 2/	1,400,000 2/	1,520,000 2/	1,300,000 3/	1,280,000 3/
Rutile concentrate, natural and synthetic:					
Imports for consumption	318,000	324,000	336,000	387,000	344,000
Consumption	480,000	398,000	489,000	421,000	494,000
Sponge metal:					
Imports for consumption	7,560	10,100	16,100	10,900	6,000
Consumption	21,500	28,400	32,000	28,200	18,100
Price, December 31, dollars per pound	$4.24-$4.50	$4.25-$4.50	$4.25-$4.50	$4.25-$4.50	$3.70-$4.80
Titanium dioxide pigment:					
Production	1,250,000	1,230,000	1,340,000	1,330,000	1,350,000
Imports for consumption	183,000	167,000	194,000	200,000	225,000
Consumption, apparent 4/	1,130,000	1,070,000	1,130,000	1,140,000	1,160,000
Price, December 31, dollars per pound:					
Anatase	$.92 - $.96	$1.06 - $1.08	$1.01 - $1.03	$.96 - $.98	$.92 - $.94
Rutile	$.92 - $.96	$1.08 - $1.10	$1.04 - $1.06	$.97 - $.99	$.99 - $1.02
World production:					
Ilmenite concentrate 5/	4,010,000	4,010,000	4,070,000	4,140,000 r/	3,780,000 e/
Rutile concentrate, natural 5/	416,000	366,000	406,000 r/	441,000 r/	390,000 e/
Titaniferous slag	1,810,000	1,830,000	1,950,000	2,050,000	2,050,000 e/

e/ Estimated. r/ Revised.

1/ Data are rounded to no more than three significant digits; except prices.

2/ Includes consumption to produce synthetic rutile.

3/ Excludes consumption 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.

TABLE 2
U.S. TITANIUM METAL PRODUCTION CAPACITY IN 1999 1/ 2/

		Yearend capacity (metric tons)	
Company	Plant location	Sponge	Ingot 3/
Allegheny Technologies Inc.	Albany, OR	6,800	10,900
	Monroe, NC	--	11,800
	Richland, WA	--	10,000
Alta Group	Salt Lake City, UT	340	--
Howmet Corp.	Whitehall, MI	--	3,200
Lawrence Aviation Industries Inc.	Port Jefferson, NY	--	1,400
RMI Titanium Co.	Niles, OH	--	16,300
Titanium Metals Corp.	Henderson, NV	14,500	13,000
	Morgantown, PA	--	24,500
	Vallejo, CA	--	450
Total		21,600	91,600

-- Zero.

1/ Data are rounded to no more than 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	1998	1999
Production:		
Ingot	52,500	40,700
Mill products	33,400	24,200
Exports:		
Sponge	348	807
Waste and scrap	7,010	8,130
Other unwrought 2/	3,880	2,470
Wrought products and castings 3/	5,800	5,260
Total	17,000	16,700
Imports:		
Sponge	10,900	6,000
Waste and scrap	9,770	6,870
Other unwrought 2/	2,650	1,610
Wrought products and castings 3/	3,900 r/	2,910
Total	27,200 r/	17,400
Stocks, yearend:		
Government: Sponge (total inventory)	31,700	31,200
Industry:		
Sponge	10,600	7,970
Scrap	13,600	9,450
Ingot	4,050	5,180
Total	28,200	22,600
Reported consumption:		
Sponge	28,200	18,100
Scrap	28,600	21,900
Receipts:		
Home	13,800	11,600
Purchased	21,600	14,500
Ingot	43,000	30,800
Mill products (net shipments):	27,500	21,600
Forging and extrusion billet	11,200	10,100
Rod and bar	3,700	3,240
Other 4/	12,600	8,270
Castings (shipments)	908	757

r/ Revised.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

2/ Includes billet, blooms, ingot, powder, sheet bar, slab, and other.

3/ Includes bars, castings, foil, pipes, plates, profiles, rods, sheets, strip, tubes, wire, other wrought and articles of titanium not elsewhere specified or included.

4/ 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, 1999 1/ 2/ 3/

Company	Plant location	Yearend capactiy (metric tons per year) Sulfate process	Chloride process	Total
E.I. du Pont de Nemours & Co. Inc.	De Lisle, MS	--	280,000	280,000
	Edgemoor, DE	--	154,000	154,000
	New Johnsonville, TN	--	352,000	352,000
Kemira, Inc.	Savannah, GA	54,000	91,000	145,000
Kerr-McGee Chemical Corp.	Hamilton, MS	--	188,000	188,000
Louisiana Pigment Co. LP	Lake Charles, LA	--	120,000	120,000
Millennium Inorganic Chemicals Inc.	Ashtabula, OH	--	190,000	190,000
	Baltimore, MD	44,000	51,000	95,000
Total		98,000	1,430,000	1,520,000

-- Zero.
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 TiO_2 pigments that is produced by refining and fine grinding of synthetic rutile.
3/ Data are rounded to no more than three significant digits; may not add to totals shown.

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

(Metric tons, unless otherwise specified)

		1998 Gross weight	1998 TiO_2 content	1999 Gross weight	1999 TiO_2 content
Production 2/		1,330,000	1,280,000 e/	1,350,000	1,300,000 e/
Shipments: 3/					
Quantity		1,380,000	1,320,000	1,430,000	1,350,000
Value	thousands	$2,540,000	$2,540,000	$2,700,000	$2,700,000
Exports		398,000	384,000 e/	384,000	368,000 e/
Imports for consumption		200,000	192,000 e/	225,000 e/	216,000 e/
Stocks, yearend		96,900	93,300 e/	137,000 e/	132,000 e/
Consumption, apparent 4/		1,140,000	1,090,000 e/	1,160,000 e/	1,110,000 e/

e/ Estimated.
1/ Data are rounded to no more than 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: U.S. Census Bureau and U.S. Geological Survey.

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

(Metric tons)

	1998		1999	
	Gross weight	TiO_2 content	Gross weight	TiO_2 content
Ilmenite and titanium slag: 2/ 3/				
Pigments	1,290,000	NA	1,270,000	NA
Miscellaneous 4/	14,000	NA	13,400	NA
Total	1,300,000	980,000	1,280,000	963,000
Rutile, natural and synthetic:				
Pigments	384,000	NA	469,000	NA
Miscellaneous 4/	37,300	NA	25,800	NA
Total	421,000	392,000	494,000	413,000
Total concentrates:				
Pigments	1,670,000	NA	1,740,000	NA
Miscellaneous 4/	51,300	NA	39,100	NA
Total	1,730,000	1,370,000	1,780,000	1,380,000

NA Not available.
1/ Data are rounded to no more than 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 7
U.S. CONSUMPTION OF TITANIUM PRODUCTS 1/ 2/
IN STEEL AND OTHER ALLOYS

(Metric tons)

	1998	1999
Carbon steel	3,180 r/	3,630
Stainless and heat-resisting steel	1,410	1,760
Other alloy steel (includes HSLA and tool steel)	580 r/	676
Total steel	5,170	6,060
Superalloys	845 r/	681
Alloys, other than above	329 r/	586
Miscellaneous and unspecified	71 r/	79
Total consumption	6,410 r/	7,410

r/ Revised.
1/ Includes ferrotitanium, titanium scrap, and other titanium additives.
2/ Data are rounded to no more than three significant digits; may not add to totals shown.

TABLE 8
U.S. DISTRIBUTION OF TITANIUM PIGMENT
SHIPMENTS, TITANIUM DIOXIDE CONTENT, BY INDUSTRY 1/

(Percent)

Industry	1998	1999
Coated fabrics and textiles	0.2	0.2
Paint, varnish, lacquer	51.2	50.2
Paper	17.6	20.0
Plastics	19.5	21.0
Printing ink	2.7	0.5
Rubber	1.9	0.8
Other 2/	6.9	7.3
Total	100.0	100.0

1/ Excludes exports.
2/ Includes agricultural, building materials, ceramics, coated fabrics and textiles, cosmetics, food, and paper. Also includes shipments to distributors.

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

(Metric tons)

	1998		1999	
	Gross weight	TiO_2 content	Gross weight	TiO_2 content
Concentrates: 2/				
Ilmenite and titanium slag	380,000	270,000	489,000	343,000
Rutile, natural and synthetic	121,000	111,000	106,000	96,400
Titanium pigment 3/	96,900	91,100 e/	137,000	130,000 e/

e/ Estimated.

1/ Data are rounded to no more than three significant digits.

2/ Consumer stocks.

3/ Data from U.S. Census Bureau. Producer stocks only.

TABLE 10
PUBLISHED PRICES OF TITANIUM CONCENTRATES AND PRODUCTS

		1998	1999
Concentrates:			
Ilmenite, f.o.b. Australian ports	per metric ton	$72.00-$77.00	$90.00-$103.00
Rutile, bagged, f.o.b. Australian ports	do.	570.00-620.00	500.00- 530.00
Rutile, bulk, f.o.b. Australian ports	do.	470.00-530.00	435.00- 510.00
Titanium slag, 80% TiO_2, Canada 1/	do.	340.00	390.00
Titanium slag, 85%TiO_2, South Africa 1/	do.	386.00	406.00
Metal:			
Sponge	per pound	4.25- 4.50	3.70- 4.80
Ferrotitanium	do.	1.25- 1.35	2.20- 2.40
Scrap, turnings, unprocessed	do.	.30- .40	1.08- 1.12
Pigment:			
Titanium dioxide pigment, f.o.b. U.S. plants, anatase	do.	.96- .98	.92- .94
Titanium dioxide pigment, f.o.b. U.S. plants, rutile	do.	.97- .99	.99- 1.02

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

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

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

	1998		1999	
Class	Quantity (metric tons)	Value (thousands)	Quantity (metric tons)	Value (thousands)
Metal:				
Unwrought:				
Sponge	348	$1,860	807	$5,750
Waste and scrap	7,010	14,100	8,130	11,700
Other unwrought:				
Billet	543	18,900	327	8,120
Blooms and sheet bars	2,010	50,700	848	25,900
Ingot	528	9,350	683	12,600
Other	791	14,400	616	11,800
Wrought products and castings:				
Bars and rods	2,010	69,600	1,870	62,800
Other	3,780	213,000	3,390	176,000
Total metal	17,000	392,000	16,700	314,000
Ores and concentrates	59,700	5,180	9,380	5,350
Pigment and oxides:				
Titanium dioxide pigments	356,000	563,000	344,000	558,000
Titanium oxides	42,200	69,900	39,300	69,000
Total	398,000	633,000	384,000	627,000

1/ Data are rounded to no more than three significant digits, may not add to totals shown.

Source: U.S. Census Bureau.

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

Concentrate and country	1998 Quantity (metric tons)	1998 Value (thousands)	1999 Quantity (metric tons)	1999 Value (thousands)
Ilmenite:				
Australia	277,000	$18,300	252,000	$21,100
India	50,000	4,030	30,100	2,450
Norway	--	--	100	8
Sierra Leone	--	--	2,600	153
Ukraine	52,100	4,450	106,000	9,130
Total	379,000	26,800	391,000	32,800
Titanium slag:				
Canada	103,000	38,600	208,000	78,200
Norway	41,000	14,300	10,000	3,690
South Africa	481,000	186,000	459,000	183,000
Other	832	268	--	--
Total	626,000	239,000	678,000	265,000
Rutile, natural:				
Australia	84,500	36,100	72,500	28,600
Austria	5,020	2,760	--	--
Canada	5,270	2,700	22,600	19,100
Korea, Republic of	--	--	4,730	1,180
South Africa	141,000	60,700	125,000	50,600
Ukraine	10,000	4,020	--	--
Other	22	232	112	147
Total	246,000	106,000	225,000	99,700
Rutile, synthetic:				
Australia	126,000	40,200	114,000	37,000
India	9,850	4,680	--	--
Malaysia	4,220	4,390	4,230	2,780
Ukraine	234	82	56	36
Other	23	3	39	33
Total	141,000	49,300	119,000	39,900
Titaniferous iron ore: 2/				
Canada	24,000	2,850	10,700	2,620

-- Zero.

1/ Data are rounded to no more than 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.

Source: U.S. Census Bureau. Data adjusted by the U.S. Geological Survey.

TABLE 13
U.S. IMPORTS FOR CONSUMPTION OF TITANIUM METAL, BY CLASS AND COUNTRY 1/

Class and country	1998 Quantity (metric tons)	1998 Value (thousands)	1999 Quantity (metric tons)	1999 Value (thousands)
Unwrought:				
Sponge:				
China	62	$536	--	--
Japan	2,660	25,300	2,070	$17,500
Kazakhstan	767	5,660	814	5,540
Russia	7,360	50,800	2,570	16,400
United Kingdom	30	191	417	2,210
Other	34	246	135	505
Total	10,900	82,800	6,000	42,200
Waste and scrap:				
Canada	204	489	264	409
France	1,210	4,770	955	2,160
Germany	232	941	479	1,380
Japan	2,590	9,490	1,790	6,420
Russia	1,040	6,010	692	1,940
United Kingdom	2,440	6,840	1,090	2,840
Other	2,050	6,070	1,600	4,400
Total	9,770	34,600	6,870	19,500
Ingot and billet:				
China	348	3,210	347	4,760
Russia	1,630	30,000	787	10,600
United Kingdom	143	2,570	113	3,660
Other	118	1,660	134	1,450
Total	2,240	37,400	1,380	20,400
Powder	147	1,590	224	1,170
Other: 2/				
Japan	137	2,150	1	260
Russia	3	26	9	92
Other	124 r/	2,090 r/	--	71
Total	264 r/	4,270 r/	10	423
Wrought products and castings: 3/				
Japan	755	21,400	566	17,200
Russia	2,360	33,700	1,520	30,300
United Kingdom	268	12,800	118	6,240
Other	510	21,800	707	20,300
Total	3,900	89,700	2,910	74,100

r/ Revised. -- Zero.
1/ Data are rounded to no more than 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.

Source: U.S. Census Bureau.

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

Country	1998 Quantity (metric tons)	1998 Value (thousands)	1999 Quantity (metric tons)	1999 Value (thousands)
80% or more titanium dioxide:				
Australia	2,730	$5,730	6,230	$11,600
Belgium	3,280	5,850	3,740	6,450
Canada	74,000	124,000	75,200	129,000
China	2,960	3,540	5,650	6,660
Finland	1,070	2,420	3,220	6,650
France	5,010	7,670	6,080	10,300
Germany	26,900	52,500	25,900	52,800
Italy	896	1,330	3,380	5,830
Japan	7,260	18,300	12,900	28,000
Norway	9,760	15,500	4,310	7,580
Poland	500	869	441	660
Singapore	3,650	6,250	3,390	5,500
Slovenia	2,780	4,350	2,700	4,560
South Africa	3,170	5,350	5,380	8,790
Spain	4,860	6,950	14,000	25,100
United Kingdom	145	260	4,060	6,890
Other	2,900	4,660	13,200	20,700
Total	152,000	266,000	190,000	337,000
Other titanium dioxide:				
Belgium	163	358	1,870	4,450
Canada	2,100	3,570	3,480	5,850
France	4,400	6,900	9	100
Germany	745	6,330	2,400	8,090
Italy	1,640	2,820	13	82
South Africa	4,510	7,300	--	--
Spain	4,550	7,830	20	48
United Kingdom	2,210	6,110	171	1,220
Other	1,770 r/	3,700 r/	1,350	3,700
Total	22,100	44,900	9,320	23,500
Titanium oxide:				
Australia	2,400	4,320	3,380	5,930
Belgium	2,620	3,840	1,660	2,720
Canada	297	465	487	812
China	2,560	2,910	3,470	3,670
Czech Republic	1,550	2,700	2,240	3,960
France	10,100	13,400	7,850	11,900
Germany	1,520	3,330	809	1,830
Other	4,740	12,200	5,830	15,000
Total	25,800	43,100	25,700	45,900
Grand total	200,000	354,000	225,000	406,000

r/ Revised. -- Zero.

1/ Data are rounded to no more than three significant digits; may not add to totals shown.

Source: U.S. Census Bureau.

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

(Metric tons)

Concentrate type and country	1995	1996	1997	1998	1999 e/
Ilmenite and leucoxene: 3/					
Australia:					
Ilmenite	1,980,000	2,028,000	2,233,000	2,379,000	1,990,000 4/
Leucoxene	31,000	33,000	32,000	30,000 r/	32,000 4/
Brazil 5/	102,125	97,955	97,174	103,000 r/	103,000
China e/	160,000	165,000	170,000	175,000	180,000
India e/	290,000	330,000	332,000 r/	378,000 r/	378,000
Malaysia	151,680	244,642	167,504	124,689 r/	127,695 4/
Norway	833,238	746,583	750,000 e/	590,000 e/	590,000
Sri Lanka	49,655	62,810	17,970 r/	34,118 r/	35,000
Thailand	33	--	--	--	--
Ukraine e/	359,000 4/	250,000	250,000	250,000	250,000
United States	W	W	W	W r/	W
Vietnam e/	50,000	50,000	50,000	80,000	92,000
Total	4,010,000	4,010,000	4,070,000	4,140,000 r/	3,780,000
Rutile:					
Australia	195,000	180,000	214,000 r/	241,000 r/	190,000 4/
Brazil	1,985	2,018	1,742	1,800 r/ e/	1,800
India e/	14,000	15,000	14,000	16,000 r/	16,000
South Africa e/	90,000	115,000	123,000	130,000 r/	130,000
Sri Lanka	2,697	3,532	2,970	1,930 r/ e/	2,000
Ukraine e/	112,000 4/	50,000	50,000	50,000	50,000
United States	W	W	W	W r/	W
Total	416,000	366,000	406,000 r/	441,000 r/	390,000
Titaniferous slag: 6/					
Canada e/	815,000	825,000	850,000	950,000	950,000
South Africa e/	990,000	1,000,000	1,100,000	1,100,000	1,100,000
Total	1,810,000	1,830,000	1,950,000	2,050,000	2,050,000

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

1/ Totals and estimated data are rounded to no more than three significant digits; may not add to totals shown.

2/ Table includes data available through July 14, 2000.

3/ Ilmenite is also produced in Canada and South Africa, but this output is not included here because most 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/ Slag is also produced in Norway, but this output is not included under "Titaniferous slag" to avoid duplicative reporting.