Titanium

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The years 1978 and 1979 were outstanding ones for titanium, with U.S. mill product shipments reaching a new record each year. In 1979, the sponge metal production rate was approaching estimated industry capacity of about 23,000 tons per year.[3] The main factor in the strong market for titanium metal was the greatly increased rate of orders for commercial airliners. Demand was such that lead times for mill product deliveries rose to 70-80 weeks or more, compared with 12-24 weeks in 1977. Domestic production and consumption of titanium dioxide pigment products increased moderately in both 1978 and 1979. Production of ilmenite and rutile decreased considerably in 1978, mainly because of mine shutdowns at Lakehurst, N.J., and Green Cove Springs, Fla. However, ilmenite production rebounded in 1979 to about the 1977 level, despite the November 1979 closure of a mine at Boulougne, Fla.

Prices for titanium mineral concentrates except ilmenite, and for titanium products increased in 1978 and 1979, especially those for rutile concentrate, titanium pigment, and sponge metal, which rose about 60%, 20%, and 35%, respectively.

Legislation and Government Programs.—The Government stockpile goal for titanium sponge metal remained at 131,503 tons during 1978 and 1979. The quantity of specification titanium sponge metal in the Government stockpile in December 1979 was 21,465 tons. In addition, there was 10,866 tons of nonspecification material.

Table 1.—Salient titanium statistics

	1975	1976	1977	1978	1979
United States:					
Ilmenite concentrate:					
Mine shipments ... short tons	702,252	617,896	542,333	580,878	646,399
Value ... thousands	$26,946	$27,578	r$25,201	$25,628	$32,965
Imports ... short tons	122,010	168,402	334,990	308,671	184,478
Consumption ... do	747,821	822,259	866,504	792,289	791,063
Titanium slag:					
Imports ... do	212,682	171,624	150,564	149,172	111,210
Consumption ... do	147,965	203,964	149,454	128,826	144,708
Rutile concentrate, natural and synthetic:					
Imports ... do	224,499	281,712	123,800	289,617	283,479
Consumption ... do	231,430	237,718	185,419	263,184	313,761
Sponge metal:					
Imports for consumption ... do	4,190	1,778	2,387	1,476	2,488
Consumption ... do	17,626	13,315	16,236	19,854	23,937
Price, Dec. 31, per pound	$2.70	$2.70	$2.98	$3.28	$3.98
Titanium dioxide pigments:					
Production ... short tons	603,429	712,940	687,103	700,755	724,887
Imports for consumption ... do	25,918	68,497	114,810	117,708	104,968
Apparent consumption ... do	595,516	753,947	785,003	801,728	810,218
Price, Dec, 31, cents per pound:					
Anatase	38.5	41.0	43.5	46.0	53.0
Rutile	43.5	46.5	48.5	51.0	59.0
World production:					
Ilmenite concentrate ... short tons	3,194,028	r3,490,031	r3,653,264	p3,861,397	e3,848,714
Titanium slag ... do	831,505	r901,193	r764,514	p1,037,193	e856,040
Rutile concentrate, natural ... do	[1]421,532	r[1]444,806	r[1]380,833	p[1]331,951	e[1]398,173

e Estimate. p Preliminary. r Revised.
[1] Excludes U.S. production data to avoid disclosing company proprietary data.

The Government stockpile goal for rutile concentrate remained at 173,928 tons, and total rutile stockpile inventory in December 1979 was 39,186 tons.

In September 1978, the U.S. Department of the Treasury received a complaint from SCM Corp. alleging that titanium dioxide imported into the United States from Belgium, the Federal Republic of Germany, France, and the United Kingdom was being sold at less than fair value. Investigations carried out by the Treasury Department under the Antidumping Act of 1921, as amended, resulted in the determination that such sales at less than fair value had taken place. However, investigations by the International Trade Commission to determine the extent of any injury to a U.S. industry from these sales at less than fair value resulted in a determination in November 1979 that no such injury had occurred or was likely to occur.[4]

The Federal Trade Commission (FTC) in April 1978 charged E. I. du Pont de Nemours and Co., Inc., with attempting to monopolize the production of titanium dioxide pigments and engaging in unfair methods of competition. In September 1979, an administrative law judge for the FTC dismissed these allegations,[5] and an FTC hearing officer ruled that the agency should drop its charges against the company.

A Federal grand jury in Pittsburgh, Pa., in September 1978 indicted four producers of titanium mill products, and some of their officers, on price-fixing charges. The trial and sentencing were completed in May 1979. One individual pleaded guilty and the other eight defendants pleaded nolo contendere. The defendant companies in the trial were Martin Marietta Aluminum, Inc., RMI Co., Crucible, Inc., and Lawrence Aviation Industries, Inc. Titanium Metals Corporation of America (TMCA) was named as an unindicted coconspirator. A civil suit filed by the U.S. Justice Department against all these companies was still pending at the end of 1979.[6]

In efforts to alleviate the shortage of titanium by encouraging imports, the following two bills were introduced in 1979: H.R. 3591, on April 10, to reduce temporarily the duty on titanium sponge, from 18% to 9% ad valorem, until June 30, 1981; and H.R. 4738, on July 11, to reduce temporarily the duty on titanium sheet, plate, and other rolled titanium products, from 18% to 9% ad valorem, until June 30, 1981. Under the Tokyo Round of negotiations completed in 1979, the most-favored-nation duty on the above forms of titanium was scheduled to be reduced in several stages to 15%, over the period January 1, 1980, to January 1, 1987. The suspension of duty on waste and scrap titanium was extended until June 30, 1981, as provided by Public Law 95-508. The duty on titanium dioxide, 7.5% ad valorem, most-favored-nation, was not affected by the Tokyo negotiations.

H.R. 2297 was introduced on February 21, 1979, to continue until June 30, 1982, the existing suspension of duties on synthetic rutile.

DOMESTIC PRODUCTION

Concentrates.—Production of ilmenite decreased in 1978 for the fifth consecutive year, but reversed the trend in 1979 by rebounding to near the 1977 production level. The decrease in 1978 was caused mainly by the shutdown, because of depleted reserves, of the SCM Corp. sand mining operation near Lakehurst, N.J., in March 1978. The increased production in 1979 was achieved despite the shutdown of the Titanium Enterprises (TE) mining and wet milling facilities at Green Cove Springs, Fla., in June 1978. However, TE continued operation of its dry mill, producing some ilmenite as well as zircon and monazite from stockpiled tailings. In November 1979, Humphreys Mining Co. ceased operations at its Boulougne, Fla., deposit because of depleted reserves. Production at the mines of Du Pont at Starke, and Highland, Fla., and of ASARCO, Incorporated, at Manchester, N.J., was comparable to their 1977 output. Production by NL Industries, Inc., Tahawus, N.Y., was over 50% higher in 1979 than in 1977 or 1978. Production of rutile concentrate has been insignificant since the TE mine shutdown in June 1978. The other Florida producers recovered some rutile in bulk concentrates consisting mainly of ilmenite and leucoxene.

In April 1980, the TE property was purchased by Associated Minerals Consolidated, Ltd. (AMC) of Australia for $11.7 million. AMC expected to produce at Green Cove Springs, over the next 16 years, 50,000 tons per year of ilmenite, 25,000 tons per year of rutile, and 25,000 tons per year of zircon, as well as smaller amounts of leu-

Table 2.—Production and mine shipments of ilmenite concentrates[1] from domestic ores in the United States

Year	Production gross weight (short tons)	Shipments		
		Gross weight (short tons)	TiO_2 content (short tons)	Value (thousands)
1975	717,281	702,252	404,269	$26,946
1976	652,404	617,896	374,989	27,578
1977	638,503	542,333	331,139	25,201
1978	589,751	580,878	352,842	25,628
1979	639,292	646,399	389,535	32,965

[1]Includes a mixed product containing rutile, leucoxene, and altered ilmenite.

Table 3.—Components of U.S. titanium metal supply and demand

(Short tons)

	1975	1976	1977	1978	1979
Production:					
Ingot	25,560	21,614	26,302	31,385	37,125
Exports:					
Sponge	NA	NA	NA	97	180
Other unwrought	NA	NA	NA	210	155
Scrap	4,326	6,144	3,394	5,453	4,967
Ingot, slab, sheet bar, etc	1,900	1,065	1,050	1,340	1,984
Other wrought	--	--	--	689	1,316
Total	6,226	7,209	4,444	7,789	8,602
Imports:					
Sponge	4,190	1,778	2,387	1,476	2,488
Scrap	876	1,860	4,494	3,789	6,154
Ingot, billet	209	323	354	561	338
Mill products	--	--	--	1,125	942
Total	5,275	3,961	7,235	6,951	9,922
Stocks, end of period:					
Government: Sponge (total inventory)	31,692	32,329	r32,331	32,331	32,331
Industry:					
Sponge	5,669	3,617	3,546	2,642	2,155
Scrap	6,132	5,764	r6,770	6,447	6,733
Ingot	r1,012	1,831	1,898	2,155	2,221
Other	35	26	42	73	200
Total industry	12,848	11,238	12,256	11,317	11,309
Reported consumption:					
Sponge	17,626	13,315	16,236	19,854	23,937
Scrap	8,316	9,211	10,889	12,318	13,986
Ingot	24,486	21,004	25,241	30,746	35,440
Mill products (net shipments)[1]	15,628	14,498	15,466	17,648	21,122
Castings (shipments)[1]	241	257	188	180	184

rRevised. NA Not available.
[1]Source: Bureau of the Census, Current Industrial Reports Series DIB-991 and ITA-991.

coxene, staurolite, and monazite.

Kerr-McGee Chemical Corp. suspended operations at its synthetic rutile plant at Mobile, Ala., on March 1, 1978, to investigate process and design modifications. The modifications were reportedly needed to allow the plant to operate at design capacity of 110,000 tons per year and be in compliance with environmental regulations. In late 1979 it was announced that this synthetic rutile plant will resume operations, and by mid-1980 should be able to supply the raw material requirements for Kerr-McGee's pigment plant in Hamilton, Miss. Total employment at the synthetic rutile plant was to be 113 people.

A comprehensive study was completed by the State of Minnesota on the copper, nickel, and titanium resources of the Duluth Complex in St. Louis and Lake Counties, Minn. Titanium resources in the area were estimated at more than 220 million tons of magnetite-ilmenite ore containing over 10% TiO_2.[7]

U.S. Titanium Corporation, a New York firm, was reportedly planning to mine the

Piney River, Va., titanium deposit formerly owned by American Cyanamid Corp. to recover ilmenite for pigment manufacture, and calcium phosphate for fertilizer production. U.S. Titanium in 1978 agreed to pay $9,240 for replacement of Piney River fish that were killed in 1977 by runoff from waste copperas (ferrous sulfate), which was left on the property from the previous pigment manufacturing operation. U.S. Titanium also agreed to remove the copperas, estimated at 60,000 to 100,000 tons[8], and in January 1980 was ordered by a Virginia judge to pay $100,000 into an escrow account to cover the costs of removal, and to complete removal of the waste by December 31, 1980.[9]

Ferrotitanium.—Ferrotitanium was produced by Shieldalloy Corp. at Newfield, N.J., by the Pesses Co. at Solon, Ohio, and by Reactive Metals and Alloys Corp., West Pittsburg , Pa. Most of the production consisted of the 70% titanium grades.

Metal.—Production of titanium sponge metal in 1978 was 29% higher than in 1977, and in 1979 was 24% higher than in 1978.

Oregon Metallurgical Corp. rebuilt its titanium sponge metal plant which had been severely damaged by an explosion and fire in October 1977, and resumed production in March 1978. The production rate in 1979 was expected to be close to full capacity.

Sponge producing companies during 1978 and 1979 and their approximate annual capacities were TMCA, Henderson, Nev., jointly owned by NL Industries, Inc., and Allegheny-Ludlum Steel Corp., 13,000 tons; RMI Co., Ashtabula, Ohio, owned by National Distillers & Chemical Corp. and United States Steel Corp., 7,500 tons; and Oregon Metallurgical Corp., Albany, Oreg., publicly owned with Armco Steel Corp. and Ladish Corp. as major stockholders, 2,500 tons. The following eight companies produced titanium ingot:

Company	Plant location
Crucible, Inc., Colt Industries	Midland, Pa.
Howmet Corp., Alloy Div	Whitehall, Mich.
Lawrence Aviation Industries, Inc	Port Jefferson, N.Y.
Martin Marietta Aluminum, Inc	Torrance, Calif.
Oregon Metallurgical Corp	Albany, Oreg.
RMI Co	Niles, Ohio.
Teledyne Allvac	Monroe, N.C.
Titanium Metals Corp. of America	Henderson, Nev.

The high demand for titanium metal which began in 1978 and intensified in 1979 led to sponge production rates close to industry capacity, and influenced sponge producers to begin expansion programs. RMI Co. announced it would expand its sponge capacity to 9,000 tons per year, the additional 1,500 tons of annual capacity to be in operation by mid-1980. RMI also began a 25% expansion of its ingot and mill product production capacity. TMCA's TIMET Division announced a 1,000-ton-per-year sponge capacity expansion to 14,000 tons per year, to be completed in late 1980 or early 1981, with further expansion to 16,000 tons per year likely in 1982-84. Oregon Metallurgical Corp. was considering a 50% expansion of sponge capacity to 3,750 tons per year.

Dow Chemical Co. and Howmet Turbine Components Corp. announced formation of a jointly owned firm, D-H Titanium Co., to scale up and commercialize an electrolytic process for the production of titanium sponge.[10] This process is based on work initiated by the Bureau of Mines during the 1960's and subsequent research conducted by Dow. Pilot plant work by Howmet reportedly indicated that unit process energy costs are about one-half those of existing commercial processes. Plans were completed for the construction of an expandable semicommercial manufacturing unit in Freeport, Tex., with startup scheduled for 1980. If this effort to develop a commercial prototype operation is successful, a commercial-scale plant, probably with about 5,000 tons per year capacity, was planned to be onstream by the mid-1980s.[11]

Pigment.—Pigment production increased in 1978 and 1979 compared with 1977. Rutile pigment accounted for 78% and 74% of total production in 1978 and 1979, respectively, and was produced by six manufacturers. Five companies produced anatase pigment. Companies producing titanium dioxide pigment during 1978-79, with plant location and estimated capacity at yearend 1979, in tons per year, were as follows:

Company and plant location	Pigment capacity (tons per year)	
	Sulfate process	Chloride process
American Cyanamid Co., Savannah, Ga	52,000	40,000
E. I. du Pont de Nemours & Co., Inc.:		
Antioch, Calif	--	35,000
De Lisle, Miss	--	150,000
Edge Moor, Del	--	167,000
New Johnsonville, Tenn	--	228,000
Kerr-McGee Chemical Co., Hamilton, Miss	--	52,000
NL Industries, Inc., Sayreville, N.J	100,000	--
Gulf + Western Natural Resources Group, Chemicals Div. (formerly New Jersey Zinc Co.):		
Ashtabula, Ohio	--	29,000
Gloucester City, N.J	44,000	--
SCM Corp., Glidden Pigments Group, Chemical/Metallurgical Div.:		
Ashtabula, Ohio	--	42,000
Baltimore, Md	53,000	30,000
Total	249,000	773,000

Du Pont completed construction of its 150,000-ton-per-year chloride process pigment plant at DeLisle, Miss. Production began in late 1979 and was to be increased gradually as demand grows.

Early in 1978, NL Industries Inc. ceased production of pigment from concentrates at its St. Louis, Mo., plant, restricting its output at that location to pigment slurry made from pigment manufactured at other plants. The company's decision was said to be based on market considerations and environmental compliance costs. The St. Louis plant was closed permanently in 1979.

In May 1979, NL Industries announced the combination of its Industrial Chemicals Div. and its Worldwide Titanium Pigment Group into one operational unit, to be known as NL Chemicals, with headquarters in Hightstown, N.J.

In December 1979, it was reported that Glidden Pigments Group of SCM Corp. was planning to expand TiO_2 pigment production capacity by up to 20,000 tons at its Ashtabula, Ohio, and Baltimore, Md., plants.

In August 1979, two producers of sulfate process pigment reported arrangements for the sale of byproduct gypsum from their waste acid neutralization plants. Gypsum from American Cyanamid Co.'s Savannah, Ga., plant was to be converted by an adjacent Lemco, Inc., plant into briquettes for use by the cement industry. SCM Corp. was selling byproduct gypsum from its Baltimore, Md., plant to a local wallboard manufacturer.

The use of TiO_2 pigment in slurry form continued to grow. Slurry shipments reportedly doubled in 5 years to an estimated 145,000 tons in 1978, or 20% of total U.S. pigment production.

Table 4.—Components of U.S. titanium dioxide pigment supply and demand

(Short tons)

	1975	1976	1977	1978	1979[p]
Production	603,429	712,940	[r]687,103	700,755	724,887
Shipments: [1]					
Quantity	576,097	711,774	696,552	714,547	NA
Value (thousands)	$423,701	$594,846	$602,383	$621,909	NA
Imports	25,918	68,497	114,810	117,708	104,968
Exports	15,807	20,580	16,336	37,812	49,369
Stocks, end of period	[r]106,963	[r]113,873	[r]114,447	93,370	63,638
Apparent consumption[2]	595,516	753,947	785,003	801,728	810,218

[r]Revised. [p]Preliminary. NA Not available.
[1]Includes interplant transfers.
[2]Apparent consumption = production plus imports minus exports minus stock increase.

Source: U.S. Bureau of the Census.

CONSUMPTION AND USES

Concentrates.—The total amount of TiO_2 consumed domestically in concentrates increased from 801,000 tons in 1977 to 886,000 tons in 1979. During that period, the market share of TiO_2 in ilmenite dropped from 65% to 55%, that of TiO_2 in slag dropped from 13% to 12%, while the proportion of TiO_2 consumed as rutile increased from 22% to 33%. This increase in rutile consumption was partly due to Kerr-McGee's return to using natural rutile following shutdown of its beneficiated ilmenite (synthetic rutile) plant in 1978.

NL Industries developed a well-drilling mud based on ilmenite and in 1979 was marketing an ilmenite product for this application. Advantages of ilmenite over barite, which is used in conventional drilling muds, include higher density and durability, and lower viscosity at a specified mud density. About 2.5 million tons of barite was used in domestic drilling muds in 1979.

Metal.—Increased demand was reported for all mill product categories in 1978 and 1979, except for a 9% to 10% drop in shipments of sheet, strip and plate, and pipe and tubing, in 1978. The strong market was due mainly to a sharply increased rate of ordering for commercial aircraft such as the Boeing 747, Lockheed L1011, and McDonald-Douglas DC10 in 1978, and to peaking of demand for commercial airframes, military programs, and tubing for nuclear powerplant condensers in 1979. Titanium tubing for desalination units to be installed in the Middle East was also a major application in 1979.

Factors influencing demand were the placing of orders by large aerospace firms to fill both actual requirements and anticipated new orders, and the need for producers, fabricators, and users to build larger work-in-process inventories.[12] As a result of this heavy demand, a shortage of titanium metal developed in 1978 and continued through 1979, with delivery lead times for mill products rising to 70-80 weeks compared with 12-24 weeks in 1977. A reduction of demand during 1980 was expected by some industry sources, which along with increased domestic production and imports may ease the shortage by late 1980 or early 1981.

It was estimated that in 1978 and 1979 consumption of titanium mill products, allowing for the scrap generated and used for making steel and other alloys, was about 60% for aerospace uses, 20% for powerplant and chemical industry application, and 20% for alloying purposes. Neglecting the scrap generated, mill products usage was about 75% for aerospace and 25% for other industrial uses.

The main nonaerospace industrial applications of titanium in 1978 and 1979 were as pipe and tubing for surface condensers in powerplants, for heat exchangers in the chemical industry, and for desalination evaporators; as sheet and strip for titanium electrodes, chiefly anodes for production of chlorine and sodium chlorate; as plate, pipe,

Table 5.—Consumption of titanium concentrates in the United States, by product

(Short tons)

Year and product	Ilmenite[1]		Titanium slag		Rutile	
	Gross weight	TiO_2 content[e]	Gross weight	TiO_2 content[e]	Gross weight	TiO_2 content[e]
1975	747,821	432,409	147,965	104,585	231,430	218,923
1976	822,259	498,013	203,964	144,506	237,718	223,612
1977	[2]866,504	[2]521,194	149,454	106,201	[3]185,419	[3]173,840
1978:						
Alloys and carbide	(4)	(4)	(5)	(5)	(4)	(4)
Pigments	781,241	467,410	128,826	91,490	209,743	195,431
Welding-rod coatings and fluxes	(4)	(4)	--	--	8,979	8,427
Miscellaneous[6]	11,048	8,038	--	--	44,462	41,326
Total	792,289	475,448	128,826	91,490	263,184	245,184
1979:						
Alloys and carbide	(4)	(4)	(5)	(5)	(4)	(4)
Pigments	775,681	475,342	144,708	106,346	247,334	230,776
Welding-rod coatings and fluxes	(4)	(4)	--	--	10,480	9,947
Miscellaneous[6]	15,382	11,886	--	--	55,947	52,189
Total	791,063	487,228	144,708	106,346	313,761	292,912

[e]Estimate.
[1]Includes a mixed product containing rutile, leucoxene, and altered ilmenite.
[2]Includes estimate of imported ilmenite used to make synthetic rutile in the United States.
[3]Includes imported synthetic rutile, but excludes synthetic rutile made in the United States from imported ilmenite.
[4]Included with "Miscellaneous" to avoid disclosing company proprietary data.
[5]Included with "Pigments" to avoid disclosing company proprietary data.
[6]Includes ceramics, chemicals, glass fibers, and titanium metal.

Table 6.—Distribution of titanium-pigment shipments, titanium dioxide content, by industry

(Percent)

Industry	1975	1976	1977	1978	1979
Paints, varnishes, lacquers	58.7	51.1	52.0	47.9	47.4
Paper	19.0	21.4	20.7	20.8	21.8
Plastics (except floor covering and vinyl-coated fabrics and textiles)	7.4	10.6	11.7	11.6	11.8
Rubber	2.8	2.7	3.1	2.8	2.9
Ceramics	1.9	1.9	1.9	2.1	1.9
Other	7.6	9.4	8.2	8.7	9.0
Exports	2.6	2.9	2.4	6.1	5.2
Total	100.0	100.0	100.0	100.0	100.0

and tubing for chemical process equipment; and in miscellaneous applications including marine, and steam turbines.[13]

Pigment.—Pigment consumption increased only about 3% from 1977 to 1979, despite a 6% increase in production during that period. Titanium dioxide long-term growth outlook was estimated by major producers at 2% to 3% per year.[14]

Ferrotitanium.—Consumption of ferrotitanium and titanium metal scrap in steel and other alloys increased about 6% in 1979, mainly because of a 61% increase in the amount used in superalloys. A projection was made in 1979 that increased production of high strength steels from about 5 million tons to 10 million tons annually by the 1980s could require an additional 600 to 700 tons per year of titanium additives.[15]

Table 7.—Consumption of titanium products[1] in steel and other alloys

(Short tons)

	1975	1976	1977	1978	1979
Carbon steel	804	976	780	601	529
Stainless and heat-resisting steel	1,117	2,008	2,049	2,394	2,368
Other alloy steel (includes HSLA)	838	818	859	936	959
Tool steel	W	W	W	W	W
Total steel[2]	2,759	3,802	3,688	3,931	3,856
Cast irons	96	100	92	144	129
Superalloys	585	455	482	743	1,197
Alloys, other than above	1,548	768	537	255	234
Miscellaneous and unspecified	182	273	r16	9	9
Total consumption	5,170	5,398	r4,815	5,082	5,425

rRevised. W Withheld to avoid disclosing company proprietary data; included in "Miscellaneous and unspecified."
[1]Includes ferrotitanium containing 20% to 70% titanium and titanium metal scrap.
[2]Except for data withheld and for unspecified included under "Miscellaneous and unspecified."

STOCKS

Stocks of titanium concentrates in the United States are shown in table 8.

Table 8.—Stocks of titanium concentrates in the United States, December 31

(Short tons)

	Gross weight	TiO_2 content[e]
Ilmenite:		
1977	r805,020	r494,658
1978	e810,757	510,430
1979	728,620	462,217
Titanium slag:		
1977	r62,581	r44,464
1978	105,685	75,097
1979	75,089	56,917
Rutile:		
1977	r146,200	r136,935
1978	e183,793	172,685
1979	e127,453	120,070
Titanium pigment:[1]		
1977	NA	114,447
1978	NA	93,370
1979	NA	63,638

eEstimate. rRevised. NA Not available.

[1]Source: U.S. Bureau of the Census.

PRICES

Concentrates.—Price quotations for ilmenite in domestic markets, $55 per long ton at the beginning of 1978, decreased to $50 in August 1978 and remained at that level until December 1979 when they increased to $55 per long ton. Australian ilmenite prices increased from $17-$19 per long ton in 1978 to $18-$19 per long ton f.o.b. Australian ports in January 1979, at which level they closed the year.

Rutile concentrate spot prices, f.o.b. Atlantic and Great Lakes ports, rose from $300-$325 per short ton to $325-$350 in August 1978, to $350-$375 in January 1979, to $375-$400 in June 1979 and to $425-$450 per short ton at yearend. Australian rutile, f.o.b. Australian ports, began 1978 at $185-$195 per short ton, increased in November 1978 to $230-$250, further increased in August 1979 to $348-$369, and ended the year with prices of $291-$332 for bulk lots and $322-$352 per short ton for bagged lots. Declared valuations of synthetic rutile imports at foreign ports of shipment averaged $151 for 1978 and $162 for 1979, while c.i.f. values averaged $169 for 1978 and $181 for 1979 per short ton.

The price of titanium slag, f.o.b. Sorel, Quebec, increased in March 1978 from $102.50 per long ton to $110 per long ton,

where it remained through the end of 1979.

Metal.—The published price of domestic titanium sponge climbed in September 1978 from $2.98 per pound to $3.28 per pound, to $3.98 per pound in March 1979, and remained at that level through the rest of the year. Japanese sponge increased from $2.50-$2.65 per pound to $2.80-$2.95 at the start of 1978, to $3.10-$3.30 in August 1978 and to $3.60 per pound in January 1979, where it remained through yearend. Quotations for mill products, per pound, during the period were bar, $7.48 to $10.73; billet, $4.86 to $7.13; plate $6.50 to $9.04; and sheet and strip, $11.90 to $14.10.

Pigment.—Published prices of titanium dioxide pigment in January 1978 were 48.5 cents per pound for rutile and 43.5 cents per pound for paper-grade anatase, and were raised periodically to the following levels, for rutile and anatase, respectively: Second quarter 1978, 51.0 cents and 46.0 cents per pound; second quarter 1979, 54.5 cents and 49.5 cents per pound; and third quarter 1979, 59.0 cents and 53.0 cents per pound.

FOREIGN TRADE

Exports and imports of titanium materials are shown in tables 9 through 12.

Table 9.—U.S. exports of titanium products, by class

Class	1976		1977		1978		1979	
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)
Concentrates:								
Ilmenite	3,478	$78	21,876	$415	NA	NA	NA	NA
Rutile	1,324	399	803	328	NA	NA	9,903	$2,057
Total	4,802	477	22,679	743	NA	NA	9,903	2,057
Metal:								
Sponge	--	--	--	--	97	$351	180	1,019
Other unwrought	--	--	--	--	210	1,141	155	1,125
Scrap	6,144	8,547	3,394	5,643	5,453	8,777	4,967	18,265
Ingots, billets, slabs, etc	1,065	15,039	1,050	14,254	1,340	11,290	1,984	26,456
Other wrought	NA	NA	NA	NA	689	11,768	1,316	25,912
Total	7,209	23,586	4,444	19,897	7,789	33,327	8,602	72,777
Pigment and oxides:								
Titanium dioxide pigments	20,555	16,155	16,225	12,506	37,812	26,967	49,369	43,940
Titanium compounds except pigment grade	25	74	111	122	1,529	2,505	2,087	4,211
Total	20,580	16,229	16,336	12,628	39,341	29,472	51,456	48,151

NA Not available.

Table 10.—U.S. imports for consumption of titanium concentrates, by country[1]

Country	1977 Quantity (short tons)	1977 Value (thousands)	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Ilmenite:						
Australia	309,902	$4,590	308,649	$4,463	184,478	$2,846
Netherlands[2]	25,088	1,087	--	--	--	--
Norway	--	--	22	3	--	--
Total	334,990	5,677	308,671	4,466	184,478	2,846
Titanium slag:						
Canada	150,564	13,514	149,172	14,858	81,289	7,814
South Africa, Republic of	--	--	--	--	29,921	3,286
Total	150,564	13,514	149,172	14,858	111,210	11,100
Rutile, natural:						
Argentina[2]	7,862	1,789	--	--	--	--
Australia	88,681	18,659	242,505	45,667	140,291	25,357
Netherlands[2]	673	489	--	--	--	--
Sierra Leone	--	--	--	--	7,980	1,484
South Africa, Republic of	--	--	5,453	841	10,819	2,068
Sri Lanka	--	--	6,063	990	6,305	1,432
Other	23	3	8	1	18	113
Total	97,239	20,940	254,029	47,499	165,413	30,454
Rutile, synthetic:						
Australia	17,351	2,103	23,546	3,771	72,218	11,799
France[2]	([3])	1	--	--	--	--
India	5,500	750	11,011	1,393	22,134	3,190
Japan	3,691	682	675	142	1,243	278
Taiwan	19	5	356	68	22,471	3,838
Total	26,561	3,541	35,588	[4]5,375	118,066	19,105
Titaniferous iron ore:[5]						
Canada	82,753	2,526	51,640	1,837	153,714	4,880

[1]Adjusted by the Bureau of Mines.
[2]Country of transshipment rather than country of production.
[3]Less than 1/2 unit.
[4]Data do not add to total shown because of independent rounding.
[5]Includes materials consumed for purposes other than production of titanium commodities, principally heavy aggregate and steel furnace flux.

Table 11.—U.S. imports for consumption of titanium pigments

Country	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Australia	1,747	$971	2,573	$1,487	2,633	$1,654	6,119	$4,146
Belgium-Luxembourg	6,703	4,503	11,501	8,830	8,936	7,082	2,620	1,893
Canada	11,285	8,539	15,636	12,246	17,242	13,847	19,808	16,948
Finland	4,813	3,247	4,688	3,242	5,110	3,644	5,791	4,533
France	6,064	4,190	5,039	3,543	11,054	7,943	5,564	4,816
Germany, Federal Republic of	20,069	15,857	46,490	34,742	39,973	33,935	34,961	32,025
India	394	180	463	275	451	250	80	46
Italy	--	--	583	338	650	430	688	496
Japan	3,641	3,606	3,085	2,805	3,562	2,926	4,736	4,362
Mexico	--	--	2,241	1,716	38	23	--	--
Netherlands	229	176	843	576	954	680	20	17
Norway	1,786	1,273	3,614	2,726	1,920	1,467	2,395	1,970
South Africa, Republic of	--	--	--	--	--	--	599	351
Spain	120	65	1,264	802	3,060	2,025	9,630	7,383
Taiwan	--	--	293	240	--	--	--	--
United Kingdom	11,941	7,707	16,182	10,861	21,467	14,362	11,348	8,781
Yugoslavia	--	--	287	255	656	466	461	416
Others	25	28	28	27	2	5	148	127
Total[1]	68,816	50,341	114,810	84,712	117,708	90,741	104,968	88,310

[1]Data may not add to totals shown because of independent rounding.

Table 12.—U.S. imports for consumption of titanium metal

Class and country	1976 Quantity (short tons)	1976 Value (thousands)	1977 Quantity (short tons)	1977 Value (thousands)	1978 Quantity (short tons)	1978 Value (thousands)	1979 Quantity (short tons)	1979 Value (thousands)
Unwrought: Sponge								
China, Mainland	--	--	--	--	--	--	99	$1,533
Japan	1,360	$5,580	1,673	$6,487	756	$3,181	2,058	10,777
U.S.S.R.	256	812	469	1,581	604	2,393	330	2,260
United Kingdom	162	605	245	908	116	514	1	10
Total	1,778	6,977	2,387	8,976	1,476	6,088	2,488	14,580
Ingot and billet:								
Canada	--	--	--	--	24	295	2	49
France	--	--	--	--	--	--	2	38
Germany, Federal Republic of	--	--	--	--	1	6	(1)	(1)
Japan	--	--	--	--	6	75	13	154
U.S.S.R.	--	--	--	--	500	2,131	313	2,473
United Kingdom	--	--	--	--	30	173	8	140
Other	--	--	--	--	--	--	(1)	5
Total[2]	--	--	--	--	561	2,681	338	2,859
Waste and scrap:								
Austria	--	--	--	--	174	448	59	286
Canada	219	291	190	393	299	587	332	1,319
Germany, Federal Republic of	153	317	793	709	393	1,391	321	1,706
Japan	299	554	209	679	105	359	469	2,706
South Africa, Republic of	--	--	--	--	--	--	170	1,762
Sweden	--	--	--	--	44	112	425	1,322
Switzerland	--	--	2	6	192	354	59	264
U.S.S.R.	486	477	1,852	2,202	[3]1,863	[3]3,012	3,313	8,422
United Kingdom	421	823	1,276	2,195	556	1,522	726	3,552
Other	282	312	172	391	164	353	266	927
Total[2]	1,860	2,774	4,494	6,575	3,789	8,139	6,140	22,267
Wrought titanium:								
Canada	135	1,236	64	692	531	3,745	470	3,799
Germany, Federal Republic of	2	28	(1)	7	16	240	29	434
Japan	160	1,408	219	1,704	556	4,663	393	5,081
United Kingdom	21	114	60	261	13	169	28	312
Other	6	153	11	294	10	226	22	518
Total[2]	323	2,939	354	2,958	1,125	9,044	942	10,144

[1]Less than 1/2 unit.
[2]Data may not add to totals shown because of independent rounding.
[3]Includes 55 tons of a metal-slag mixture.

WORLD REVIEW

Australia.—Australia continued to dominate world supplies of titanium concentrates, despite increasing production of high-TiO_2 slag and rutile from the Republic of South Africa, and new production of rutile from Sierra Leone. Australian exports of ilmenite in 1978 and 1979 went mainly to the United Kingdom, the United States, France, Japan, Brazil, and Yugoslavia; rutile was exported mostly to the United States, the United Kingdom, Japan, the Netherlands, and the Federal Republic of Germany.

The world supply of rutile tightened in 1978 and 1979 as production levels at Richards Bay and Sierra Leone increased more slowly than anticipated and production was cut back at several synthetic rutile plants, leading to considerably higher prices for Australian rutile than in 1977.

Some consolidation and merging of sand mining companies took place in 1978-79. The only large-scale operators on the east coast in mid-1979 were Associated Minerals Consolidated Ltd., Mineral Deposits, Ltd., and Rutile and Zircon Mines (Newcastle) Ltd.; and on the west coast, Associated Minerals Consolidated, Westralian Sands, Ltd., Cable Sands Pty. Ltd., Allied Eneabba Pty. Ltd., and Jennings Mining Ltd.[16] In April 1979, it was reported that Du Pont would become a majority shareholder in Allied Eneabba,[17] and in September 1979 Consolidated Gold Fields Australia Ltd. and

Table 13.—Titanium: World production of concentrates (ilmenite, leucoxene, rutile, and titaniferous slag), by country

(Short tons)

Concentrate type and country	1976	1977	1978[p]	1979[e]
Ilmenite and leucoxene:[1]				
Australia:				
Ilmenite	[r]1,057,339	1,139,081	1,383,392	[2]1,258,646
Leucoxene	[r]13,595	11,708	17,752	22,000
Brazil	16,110	14,625	22,131	20,000
Finland	135,143	137,458	145,395	145,000
India	[r e]90,000	[3]151,402	[e 3]165,000	165,000
Malaysia[4]	198,410	169,388	205,929	206,000
Norway	845,101	913,267	845,461	[2]903,576
Portugal	405	252	165	200
Sri Lanka	61,524	37,580	36,421	39,000
U.S.S.R.[e]	420,000	440,000	450,000	450,000
United States[5]	652,404	638,503	589,751	[2]639,292
Total	[r]3,490,031	3,653,264	3,861,397	3,848,714
Rutile:				
Australia	429,625	358,561	283,376	[2]305,773
Brazil	56	141	402	400
India	[r e]4,000	[4]6,053	[e 4]5,500	10,000
Sierra Leone[e]	--	--	--	11,000
South Africa, Republic of[e]	--	5,000	20,000	46,000
Sri Lanka	[r]1,145	1,078	12,673	15,000
U.S.S.R.[e]	[r]10,000	10,000	10,000	10,000
United States	W	W	W	W
Total[6]	[r]444,826	380,833	331,951	398,173
Titaniferous slag:				
Canada[7]	[r]897,350	763,160	937,000	[2]525,840
Japan[7]	3,843	1,354	193	200
South Africa, Republic of[e 8]	--	--	100,000	330,000
Total	901,193	764,514	1,037,193	856,040

[e]Estimate. [p]Preliminary. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Ilmenite is also produced in Canada and in the Republic of South Africa but this output is not included here because it is almost entirely used in production of slag. (See below under titaniferous slag.)
[2]Reported figure.
[3]Data are for fiscal year beginning April 1 of year stated.
[4]Exports.
[5]Includes a mixed product containing ilmenite, leucoxene, and rutile.
[6]Except for U.S. data.
[7]Contains 70% to 72% TiO_2.
[8]Contains 85% TiO_2.

Associated Minerals Consolidated, Ltd. (AMC) announced that they had agreed to purchase Jennings Industries mineral sands operations at Eneabba and Geraldton.[18]

AMC announced that it will expand the capacity of its synthetic rutile plant at Capel to 66,000 tons per year. The company reportedly planned to eventually increase its total synthetic rutile capacity to 132,000 tons per year.

Murphyores Holdings Ltd. was reportedly planning a new $20 million operation near Gladstone in Queensland to produce about 50,000 tons of rutile and zircon, and 140,000 tons of ilmenite per year. Murphyores was also reported in the Australian press to be exerting pressure on the Federal Government to reverse its controversial decision to stop sand mining on Fraser Island.[19]

NL Industries, Inc., late in 1979 sold its subsidiary, Titanium Alloy Manufacturing Co. Pty. Ltd. (Tamco), to Utah Mining Australia, Ltd. Tamco's principal assets included an 85% interest in Mineral Deposits, Ltd., a producer of rutile and zircon concentrates and a manufacturer of mineral processing systems.

In early 1978, Dillingham Corp. announced its withdrawal from mineral sand mining in Australia, stating that the New South Wales Government's action in banning future mining in areas designated as National Parks, combined with the Federal Government's action on Fraser Island at the end of 1976, made it impossible for Dillingham to continue sand mining in Australia.

Canada.—Production of Sorelslag in 1979 by QIT-Fer et Titane, Inc. was only 56% of 1978 output because of a 4-month strike at the company's mine and smelter.

Syncrude Canada Ltd. extracts a total of about 91 million short tons of tar sands

annually from which it is estimated that 104,000 tons per year of titanium minerals will be produced. The titanium minerals consist mainly of altered ilmenite believed to be suitable for chloride process TiO_2 manufacture, or for production of synthetic rutile.[20]

China, Mainland.—Titanium sponge metal was exported to the United States for the first time during the last quarter of 1979. China is reported to have several small titanium sponge plants, with total annual capacity in the range of 1,000 to 2,000 tons, using titanium slag made from ilmenite as the main raw material for titanium tetrachloride manufacture. China also was said to be rich in rutile deposits, which occur mainly in Szechwan Province.[21] Current output of titanium dioxide pigment is thought to be about 15,000 to 20,000 tons per year from plants in Peking and Shanghai.

European Economic Community (EEC).—An EEC directive adopted in February 1978 made each country responsible for monitoring its own waste disposal sites and for developing plans to reduce pollution. In mid-1979, exceptions were denied to United Kingdom and Federal Republic of Germany TiO_2 producers, who had applied for exemptions from the directive on the grounds that the conditions pertaining to their disposal situations did not constitute a pollution threat.

There have repeatedly been reports of plans by West European firms to build a 5,000-ton-per-year titanium sponge plant, possibly as a joint venture, to produce material for the EEC market. The companies mentioned in these reports include Pechiney Ugine Kuhlmann Corp., Thyssen AG, Fried. Krupp Huettenwerke AG, and Metallgesellschaft AG.

United Kingdom.—The National Enterprise Board (NEB) announced in late 1979 that it will go ahead with initial plans to construct a new $55 million titanium sponge plant in Shotton, North Wales, in cooperation with state-owned Rolls-Royce Ltd. and IMI Ltd. The new plant will have a capacity of 5,500 tons per year, and will replace the Imperial Chemical Industries Ltd. Teeside facility, which was scheduled to be closed in 1982. The NEB indicated it would seek to transfer its financial participation to the private sector and said it had already received inquiries from a number of interested companies.

India.—A 24,000-ton-per-year chloride process TiO_2 pigment plant was being built by Kerala Minerals and Metal Ltd. (KMML) at Kojlthotham near Quilon, Kerala State. KMML also planned to build a Benilite process synthetic rutile plant. Initial production from a new mineral sands separation plant to be built near the pigment plant was to be about 100,000 tons per year by 1981-82. KMML has been supplying ilmenite to Travancore Titanium Products Ltd.'s sulfate process TiO_2 plant at Quilon. Reserves of the Quilon district were reported to be 39 million tons of ilmenite.

The Orissa Sands Complex Project near Chatrapur, Orissa, was under development, and was expected to produce 220,000 tons of ilmenite in its first phase, possibly by late 1981. A 110,000-ton-per-year synthetic rutile plant was also planned, followed by a second phase of development involving construction of a TiO_2 pigment plant. Reserves of ilmenite in the Chatrapur area were said to be about 250 million tons.[22]

Japan.—In response to the very strong demand for titanium, both Japanese sponge producers expanded production capacity by yearend 1979, as follows: Osaka Titanium Co. Ltd., from 6,600 tons per year to 10,600 tons per year; and Toho Titanium Co. Ltd., from 6,000 tons per year to 7,300 tons per year. It was also planned that in 1980 Osaka would increase capacity further to 12,000 tons per year, and that Toho would raise its capacity to 9,300 tons per year. In addition, the idle sodium reduction (Hunter process) sponge plant of Metal Industry, Ltd., subsidiary of Nippon Soda Company, was to be activated in 1980, with a capacity of 2,400 tons per year, bringing Japan's total annual sponge capacity to 23,700 tons by late 1980, compared with 17,900 tons in 1979, and 12,600 tons in 1978. Japanese production of titanium sponge in 1977, 1978, and 1979 was 7,049 tons, 10,115 tons, and 14,442 tons, respectively, and production in 1980 was expected to be about 20,000 tons.

Sierra Leone.—Sierra Rutile Ltd., owned 85% by Bethlehem Steel Corp. subsidiaries and 15% by Nord Resources Corp., began mining rutile in Sierra Leone from the Mogbwemo deposit about 80 miles southeast of Freetown. Sierra Rutile produced somewhat less than its anticipated 35,000 tons in 1979, but expected to be operating close to capacity production of 110,000 tons per year in 1980. Proven ore reserves are reportedly sufficient for 20 years of production.[23]

South Africa, Republic of—Production of high-titanium slag (85% TiO_2) and rutile by Richards Bay Minerals reportedly reached about 75% of nominal capacity in 1979, and is expected to attain full capacity of 440,000

tons of slag, 62,000 tons of rutile, and 127,000 tons of zircon in 1980.

Sri Lanka.—A rutile-zircon plant was put into operation in 1978 by Ceylon Mineral Sands Corp. at Pulmoddai, with annual capacity of about 14,000 tons of rutile and 8,000 tons of zircon. An expansion program was announced in September 1979 to increase total ilmenite capacity from about 100,000 tons per year to 135,000 tons per year.

U.S.S.R.—Production of titanium sponge metal in the U.S.S.R. was estimated at 42,000 tons in 1979, 8% higher than in 1977. One of the factors contributing to the titanium shortage, particularly in Western Europe, was the much lower volume of titanium sponge exports by the U.S.S.R. in 1978-1979. Possible reasons cited for the lower exports were increased Soviet use in industry and accelerated commercial and military aircraft programs. There were also reports that the Soviet Union has built and tested a titanium-hulled nuclear-powered submarine;[24] such vessels, if the hulls were made entirely of titanium, would probably each require several thousand tons of titanium mill products.

TECHNOLOGY

Bureau of Mines technical publications related to titanium include reports on the design and construction of an apparatus to provide a direct measure of the electron-to-atom transfer ratio in molten salts, such as in the $NaCl$-$TiCl_2$-$TiCl_3$ system;[25] a study of hot-rolling metals in vacuum;[26] recovery of TiO_2 from slags prepared by soda-smelting ilmenite;[27] corrosion studies in high-temperature, hypersaline geothermal brines;[28] recovery of byproduct heavy minerals from sand and gravel, placer gold, and industrial mineral operations;[29] electric furnace smelting and refining of prereduced titaniferous materials;[30] static casting of small titanium and zirconium shapes;[31] electrodeposition of erosion-resistant titanium diboride coatings;[32] and a process patent for upgrading titanium-bearing materials, including ilmenite, with sulfur trioxide.[33] In a particularly important aspect of this patent, high-TiO_2 slag from the smelting of ilmenite is reacted with sulfur trioxide gas, whereby the calcium and magnesium oxide impurities are converted to double sulfates which can then be leached out of the slag with water. Bureau work was also being carried out on recovery of rutile from porphyry copper mill tailings.

A paper on arc furnace smelting of Western Australian beach sand ilmenite described the preparation of slag containing typically 89.6% TiO_2 equivalent with only 0.09% $MgO + CaO$, which was claimed, on the basis of chemical composition, to be suitable for manufacture of TiO_2 pigment by either the sulfate or the chloride process.[34] Also published in 1978 were comprehensive articles on the Titania A/S ilmenite mining operation in Norway,[35] and on Western Titanium's Hockin process for making synthetic rutile.[36]

Work directed toward cutting the cost of titanium by developing improved processes for forming titanium was continued. There are three main types of technologies which are being exploited for this purpose: (1) Casting processes that solidify molten metal to obtain the desired shape;[37] (2) processes that consolidate metal powder to the desired shape, such as hot isostatic pressing;[38] and (3) processes that deform wrought metal to the desired shape, such as hot die forging and superplastic forming/diffusion bonding.[39] A critical factor in the successful use of powder consolidation processes was the development of a method for making uncontaminated alloyed titanium powder.[40]

New titanium alloys were also being developed. In 1978, RMI Co. announced a new, commercially pure titanium metal product containing only 0.05% Fe compared with 0.16% Fe in conventional unalloyed titanium. This new grade of titanium was said to have improved corrosion resistance in industrial applications, and was expected to be used mainly in the chemical, paper and pulp, power, marine, food, and pharmaceutical industries. A new alloy containing 10% vanadium, 2% iron, and 3% aluminum, developed by TIMET, was being considered by Boeing Commercial Airplane Co. for use on its new 767 airliners. This transbeta alloy has better strength-weight properties and can be forged at lower temperatures than other alloys currently used.[41]

Alloys based on the titanium aluminides (Ti_3Al and $TiAl$) reportedly have a high potential as replacements for nickel- and cobalt-base superalloys in jet engines.[42]

Westinghouse Electric Corp. announced that it received a contract from the Electric Power Research Institute to build the world's first super-conducting generator which will utilize conductors made of titanium-columbium alloy.[43]

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[1]Physical scientist, Nonferrous Metals Section.

[2]Statistical assistant, Nonferrous Metals Section.

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