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NONAEROSPACE USES OF TITANIUM

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NONAEROSPACE USES OF TITANIUM

D. J. Maykuth and R. A. Wood*

SUMMARY

In 1967, about 3.25 million pounds of titanium mill products were consumed in nonaerospace applications. The major uses were in the manufacture of chemical process equipment and in ordnance and marine applications, which collectively accounted for 92 percent of this total. By 1978, a continued expansion of these established uses can be expected to increase the mill product requirements to about 4.5 million pounds per year.

The future development of new nonaerospace markets and products is strongly dependent on economic factors. Nonetheless, it appears reasonable to expect an additional increase in mill-product requirements, arising from new uses, which may total as much as 5.5 million pounds per year by 1978.

Thus, the total demand for titanium in all nonaerospace applications could rise to a level of about 10 million pounds per year within the next 10 years. This may be considered as a very conservative estimate in terms of the total potential of titanium. However, conservative utilization of titanium has been the experience in the past.

INTRODUCTION AND ACKNOWLEDGMENTS

This memorandum was prepared during the summer of 1968 by the Defense Metals Information Center in support of the Titanium Subcommittee of the Materials Advisory Board Committee on Technical Aspects of Critical & Strategic Materials. The objective of this memorandum was to survey the current and future use patterns of titanium over the next 10 years in the following areas of nonaerospace applications:

Chemical Processing Industry
Marine and Submarine
Ordnance
Desalination
Electrochemical
Mechanical.

In conducting this survey, DMIC submitted questionnaires to four organizations that were identified as major producers of chemical process equipment. Replies were received, however, from only two of them. Information was also solicited and received in personal discussions, either by telephone or visit, with representatives of the Army and Navy in addition to Reactive Metals, Incorporated,(RMI) and the Titanium Metals Corporation of America (TMCA). Additional information was also obtained from the DMIC files.

CURRENT-USE PATTERN

Table 1 summarizes the estimated 1967 usage of titanium mill products in nonaerospace applications. This total of 3.25 million pounds represents 12 percent of the total of 27.27 million pounds of mill products that were produced that year.

TABLE 1. ESTIMATED 1967 USE PATTERN OF TITANIUM MILL PRODUCTS IN NONAEROSPACE APPLICATIONS

Use Area	Mill Product Use: Pounds	Mill Product Use: Percent of total
Chemical process industry	1,250,000	38.5
Marine		
Deep-diving submersibles	50,000	1.5
Other	700,000	21.5
Ordnance		
Direct	500,000	15.4
Indirect	500,000	15.4
Electrochemical	110,000	3.4
Mechanical	40,000	1.2
Medical prosthesis	30,000	0.9
Electronic	15,000	0.5
Miscellaneous	55,000	1.7
Totals	3,250,000	100.0

This 12 percent value is between values of 6.6 and 15.5 percent that were cited by TMCA and RMI, respectively. In DMIC's opinion, the main reason for this variance is the difficulty in identification of the products going into ordnance applications. Many of these are classified. Also, many forgings destined for ordnance use are produced by the same vendors who supply the aerospace industry and who report total production as aerospace oriented.

Table 2 identifies some of the many individual nonaerospace items that have been made. Several of the itmes listed are well established production hardware, while some have been made in amounts of only one to ten of a kind. Collectively, they reflect the diversity of nonaerospace applications in which titanium can or could serve a unique purpose.

As indicated in Table 1, the greatest nonaerospace use of titanium is in the chemical process industry, which consumed around 38 percent of the total nonaerospace titanium in 1967. Ordnance and marine applications accounted for about 31 and 23 percent, respectively, of this market. The remaining 8 percent was distributed among electrochemical, mechanical, medical prosthesis, electronic, and miscellaneous applications.

Table 3 gives some details of present and estimated future mill-product requirements by two major producers of chemical process equipment. The two sources at Company A differed widely in every detail. Also, Company B claimed 85 percent utilization of all titanium purchased, and that titanium

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TABLE 2. SUMMARY OF CURRENT NONAEROSPACE APPLICATIONS FOR TITANIUM

General Areas	Examples		
	Chemical Process Industry		
Chemical Manufacturing	Anodes	Centrifuges	Heat exchangers
Mineral Processing	Kilns	Nozzles	Reaction vessels
Metal Processing	Condensers	Ejectors	Pumps
Paper Manufacturing	Agitators	Sparge tubes	Valves
Textile Manufacturing	Driers	Filters	Piping
Food and Drug Manufacturing	Implants	Baskets	Fittings
Desalination	Tools	Hooks	Scrubber columns
Power Manufacturing	Turbine blades	Racks	Baffle columns
Mining and Petroleum	Reactor parts, scram rods	Bayonet heaters	Stills
	Fasteners	Thermowells	Mixers
	Marine Applications		
Deep-Diving Submersible Vehicles	Deckware	Stanchions	Hulls
Surface Ships	Fittings	Plates and sockets	Support rings
Surface Effect Vehicles	Piping	Inlet ports	Longerons
Auxiliary Equipment	Pumps	Exhaust ports	Buoyancy spheres
	Valves	Mufflers	Propellers
	Structures	Mines	Shafts
	Anchors	Torpedos	Hubs
	Masts	Antennae	Hydrofoils
	Booms	Tools	Struts
	Rigging hardware	Buoys (sonic detector)	
	Ordnance Applications		
Armor	Mortar base plates	Air-transportable equipment--power, communicative--medical	Vehicular plate
Weapons	Small arms shells	Man-transportable equipment--weapons, shelter, communicative, sustaining, tools, medical	Modular kits
Auxiliary Equipment	Large calibre casings	Vehicular, tank tracks	Body armor
Vehicular Transport	Projectiles (flechettes)	Man-movable, tank hatch torpedo tube breech door	Helmets
	Missiles (field nuclear)		Gun tubes
	Propellant powder		Mortar tubes, bipeds
	Incendiary powder		Portable stills
	Flare powder		Motor-generator sets
	Antennae (collapsible)		Radiator grills
	Solar cell support beams		
	Miscellaneous Applications		
Functional:	Conveyor belts	Ski poles	Foil condensers
Mechanical	Flexible shafts	Tennis rackets	Ion pumps, getters
Electrical	Cables	Golf clubs, heads, shafts,	Electron tube components
Transportation	Harmonic drive components	Golf balls, center cores	Printed circuitry
Medical Prosthesis	Connecting rods	Saltwater fishing gear	Machine parts, low inertia
Sports	Pistons	Snorkel tubes, spears, guns	Sewing machines
Hardware	Wheels	Saltwater tools, garden tools	Business machines
Decorative:	Leaf springs	Bells	Camera shutters
Automotive	Mufflers	Watchbands	Springs, coil
Architectural	Trim, automotive, etc.	Pen nibs	Endless belts
Jewelry	Prestige parts		

TABLE 3. SUMMARY OF DATA FROM MANUFACTURERS OF CHEMICAL PROCESS EQUIPMENT

	Year			
	1966	1967	1968	1973
		Company A		
Mill Products, lb				
Tubing (weld and seamless)	- -	84 to 100,000[a]	100,000[b]	140,000[b]
Sheet and plate	- -	40 to 155,000[a]	60,000[b]	80,000[b]
Bar stock	- -	1 to 12,000[a]	2,000[b]	4,000[b]
Forgings	- -	1,000 or N.A.[a]	1,500[b]	3,000[b]
Wire	- -	5,000 or N.A.[a]	8,000[b]	15,000[b]
Total		125,000 to 272,000	171,500[b]	242,000[b]
Ti-clad Steel (gross wt.)	500,000	135 to 500,000	150 to 250,000	150 to 250,000
Ti Grade Used, percent of total				
CP, ASTM Grade 1	- -	55	- -	- -
CP, ASTM Grade 2	- -	40	- -	- -
CP, ASTM Grade 3	- -	0	- -	- -
Ti-0.2Pd	- -	5	- -	- -
Applications, percent of total				
Heat Exchangers	- -	60	- -	- -
Reaction vessels	- -	30	- -	- -
Other equipment	- -	10	- -	- -
		Company B [c]		
Mill Products, lb				
Tubing (weld and seamless)	42,800[b]	42,800[b]	- -	- -
Sheet and plate	127,000[b]	127,800[b]	- -	- -
Bar stock	12,400[b]	12,400[b]	- -	- -
Forgings	0	0	- -	- -
Wire	2,900[b]	2,900[b]	- -	- -
Total	185,900[b]	185,900[b]	- -	- -
Ti-clad steel (gross wt)	N.A.	N.A.	- -	- -
Ti Grade Used, percent of total				
CP, ASTM Grade 1	- -	15	- -	- -
CP, ASTM Grade 2	- -	65	- -	- -
CP, ASTM Grade 3	- -	15	- -	- -
Ti-0.2Pd	- -	5	- -	- -
Applications, percent of total				
Heat exchangers	- -	35	- -	- -
Reaction vessels	- -	65	- -	- -
Other equipment	- -	- -	- -	- -

(a) Range resulted from two separate sources within company.
(b) Estimated by company.
(c) 1966 figures are the same as 1967 figures due to average monthly consumption figures reported for the 2-year period (15,500 lb/mo).

prices would have to be 25 to 35 percent lower than at present in order to show marked increase in utilization.

As shown in Table 3, unalloyed titanium tubing, sheet, and plate are the principal mill products consumed by these organizations and their principal end products are heat exchangers and reaction vessels.

Some additional statistics and comments on the present uses of titanium in various other nonaerospace categories are included in the following sections.

FUTURE USES

The future of titanium in nonaerospace applications is very much dependent upon economic factors. All sources contacted in this survey emphasized this point, and most were reluctant to estimate future usages because of the uncertainties of price, not only of titanium but also of competitive materials.

Nonetheless, we have made some estimates regarding the future usage pattern for titanium in several major nonaerospace categories. These are summarized in Table 4, which shows the projected consumption of titanium mill products in selected application areas over the period 1968 to 1978.

TABLE 4. PROJECTED CONSUMPTION OF TITANIUM MILL PRODUCTS IN NONAEROSPACE APPLICATIONS

Application	Mill-Product Consumption, 1000 lb												(a)
	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	
						1967 Applications							
Chemical process industry	1,250	1,288	1,327	1,367	1,408	1,450	1,493	1,538	1,584	1,631	1,680	1,730	A
Marine	750	772	795	81[illegible]	844	869	895	922	950	978	1,007	1,037	A
Ordnance(b)	1,000	1,030	1,061	1,093	1,126	1,160	1,195	1,231	1,268	1,306	1,345	1,385	A
Miscellaneous	250	258	264	272	280	288	297	306	315	324	334	344	A
Subtotals	3,250	3,348	3,447	3,551	3,658	3,767	3,880	3,997	4,117	4,239	4,366	4,496	
						New Applications							
Desalination	- -	- -	- -	200	[illegible]00	600	800	1,100	1,400	1,800	2,300	3,000	B
Helmets	- -	- -	225	225	225	225	225	225	225	225	225	225	C
Body armor	- -	- -	800	800	800	800	800	800	800	800	800	800	C
Steam turbines	- -	40	40	100	150	200	250	300	350	400	450	500	C
Transportation	- -	- -	- -	- -	- -	- -	500	600	700	800	900	1,000	C
Grand Totals	3,250	3,388	4,512	4,876	5,233	5,592	6,455	7,022	7,592	8,264	9,041	10,021	

(a) A - Projected growth rate of 3 percent per year.
B - See Figure 2 for "Best"DMIC Estimate.
C - See text.

(b) Not including new applications in helmets and body armor.

Chemical Process Industry

One manufacturer of chemical equipment (Table 3, Company A) has forecast a 41 percent increase in the requirements for mill products over the 1968 to 1973 period. In the light of this judgment, DMIC's projected requirements for an annual growth rate of 3 percent per year for the entire chemical process industry (Table 4) may be quite conservative.

It is also of interest to note from Table 3 that the forecasted proportions of the individual mill products required over the period of 1967 to 1973 show no significant changes. Also, unalloyed titanium will apparently continue to fulfill most of these applications, with only minor quantities of the Ti-0.2Pd alloy being required in special applications (e.g., to resist crevice corrosion in heat exchangers that circulate brine solutions).

Marine Applications

Marine applications may be considered in the following five subcategories:

(1) Deep-diving submersible (DDS) vehicle applications, which include pressure hulls, buoyancy spheres, structural parts, tanks for stores, and fittings

(2) Surface ship applications, which include piping, pumping systems, and deck fittings

(3) Unconventional vehicle applications, which include such craft as hydrofoil and surface effect (air bubble) vehicles as well as very high-speed craft of more or less conventional design

(4) Ordnance applications

(5) Dockside hardware.

A detailed accounting of the estimated current and future usage of titanium in most of these applications areas is not possible in this memorandum because of security restrictions. However, Navy and producer contacts have indicated that about 50,000 pounds of titanium mill products per year for the next 5 years will be used in the DDS programs alone. For the suceeding 5 years, this usage will double to a level of 100,000 pounds per year. Most of this material will be utilized in the design and construction of research-type submersible vehicles.

Some of the non-DDS marine applications include unalloyed, cast titanium parts such as ball valves, sonar masts, propellors, impellors, and pumps.

While there are no reliable numbers available for predicting future non-DDS titanium marine applications, we believe that the current usage will increase on the order of at least 3 percent per year, and Table 4 is predicated on this assumption. Figure 1 illustrates this projected growth rate and shows that, over this 10-year time period, only a relatively small quantity of product will be required by the DDS applications.

Unforeseen international crises could, of course, seriously affect these predictions. For example, if a full-scale military-type titanium DDS vehicle were required, the titanium requirements for the pressure hull alone would be quite large. Based on a 20-foot-diameter, 100-foot-long vehicle having a wall thickness of 6 inches, about 1.5 million pounds of titanium alloy would be required to produce a finished hull weight of about 900,000 pounds.

Ordnance Applications

A detailed itemization of current and future ordnance applications for titanium cannot be presented because of security restrictions. Some

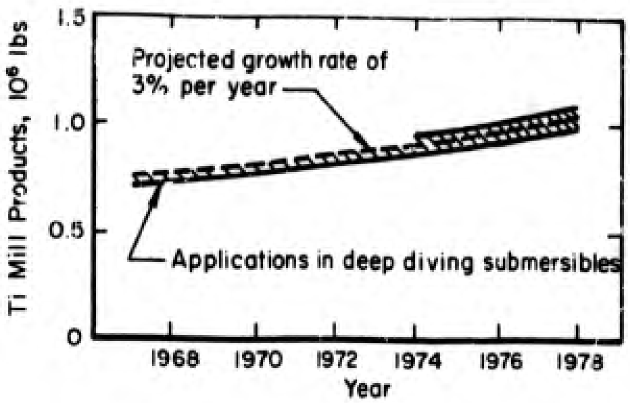

FIGURE 1. PROJECTED CONSUMPTION OF TITANIUM MILL PRODUCTS IN MARINE APPLICATIONS

available numbers are, however, quite instructing and of great potential import.

For example, prototype helmets of the Ti-5Al-2.5Sn alloy, weighing from 1.75 to 2.25 pounds each, are now being evaluated by the U. S. Army. If one of these models incorporating 1.75 pounds of titanium alloy were selected as a required item, and a million helmets were required over a 10-year period, perhaps as much as 2.25 million pounds of alloy would be required to produce the 1.75 million pounds of product. An annual requirement of 225,000 pounds of titanium alloy would result, as indicated in Table 4.

Similarly, 6.5 pounds of Ti-5Al-2.5Sn alloy are now required for each "Standard Type A, M1" body armor vest. If a million of these were manufactured over the next 10 years, the total titanium requirement might be as much as 800,000 pounds per year, again as indicated in Table 4.

Armor plate for vehicles (including helicopters) may require rather large poundages of titanium in the years ahead. For example, more than 1200 pounds of titanium armor plate has been used around crew stations, fuel cells, and the propulsion mechanisms on a single HH53B heliocopter. A ground vehicle might use more plate weight than this, depending upon vehicle size. Single orders for armor plate are known to have exceeded 200,000 pounds.

Desalination Equipment

Various industrial representatives have estimated that by 1970 to 1975, a plant capacity of 1 billion gallons per day (GPD) of desalted water will be required. A 20-fold increase in this capacity requirement is seen for 1980 to 1985. These projected capacities represent 400 million feet of tubing and 8 billion feet of tubing, respectively, for the two time periods.

If titanium represented 10 percent of this tubing requirement* the footage required would be 40 million and 800 million feet, respectively, or about 4 million and 80 million pounds of titanium, respectively.

* 10 percent, based on the assumption that the titanium would be substituted for this amount of the 70Cu-30Ni alloy.

Since the preceding projections are based on installation at uniform rates between specified points in time, it might be assumed that between 1969 and 1975, a titanium requirement of 0.66 million pounds per year would be needed. Similarly, between 1975 and 1985, about 8 million pounds per year would be the requirement. These consumption levels are shown in Figure 2 as low and high estimates, respectively. Admittedly, extrapolating a curve between such diverse limits is hazardous, at best. However, some justification for the DMIC estimate is afforded by the TMCA projected data* curves shown in Figure 2. These curves were prepared on the assumed need of a desalination plant capacity of 1 billion GPD by 1975. The upper TMCA curve indicates the predicted titanium tubing demand if the current composite price of $7.81 per pound were lowered directly to $5.50 per pound. The lower TMCA curve indicates the tubing demand that could result if the current price were decreased gradually (i.e., at a compounded rate of 5 percent per year) to $5.50 per pound.

Mechanical Applications

Steam Power Generation

Two of the major U. S. producers of steam power generating equipment are exploring the use of titanium in steam-turbine power-generation equipment. While admitting that this potential was real, spokesmen from one of these companies were doubtful that any significant quantities of titanium would be required for such applications within the next 10 years.

Further insight into the problems and potential of titanium in these applications was provided by representatives of the second company and the following appraisal is offered on the basis of discussions with representatives of that organization.

Because of their high strength/weight ratio, titanium alloys are viewed as the leading material for constructing the large turbine blades needed at the low-pressure end of high-load** generators.

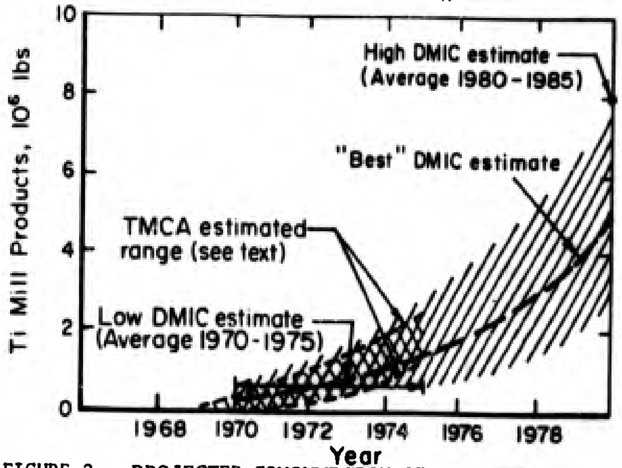

FIGURE 2. PROJECTED CONSUMPTION OF TITANIUM MILL PRODUCTS IN DESALINATION PLANT APPLICATIONS

* Private communication, (June, 1968)

** Defined as power outputs of 800,000 kilowatts and greater.

Serious technical problems must be solved before titanium can be accepted for such use. These include the possible inadequacy of titanium to withstand the erosion and fatigue conditions that will continue over the long service times desired, e.g., 100,000 hours. If these problems can be solved, the following use pattern may develop:

(1) In 1968, one turbine incorporating four rows of 38-inch-long, titanium alloy blades might be built. Approximately 40,000 pounds of mill product would be required.

(2) The number of such turbines produced could increase slowly up to a total of 10 per year by 1978. The quantity of mill products required would increase to the values shown by the lower dashed curve in Figure 3.

(3) Successful operation of the 38-inch-long blades could lead to the use of larger, 52-inch-long blades. Use of the larger blades would raise the required quantity of titanium-alloy mill products to 60,000 pounds per turbine. Thus, by perhaps 1970, the titanium requirements could correspondingly increase to the levels indicated by the upper dashed curve in Figure 3.

As a compromise estimate, DMIC has chosen (in Table 4) an average projected mill-product consumption level which is shown in Figure 3 as a solid curve.

Transportation

Numerous titanium and titanium-alloy components have been proposed for use in various mechanical devices in the transportation industry in order to capitalize on the high strength/weight ratio and/or the low elastic modulus (compared to steels) offered by these materials. Such uses include connecting rods, pistons in deisel engines, train wheels, and truck leaf springs. Further, prototype titanium-alloy parts have been evaluated in some of these applications (e.g., connecting rods) where their performance has contributed significantly to the overall efficiency of the machines. The main deterrent to accepting titanium alloys for most of these applications is purely economic.

In considering the next 10-year period, DMIC believes that the competitive costs of titanium and the more common structural materials, including steel and aluminum, will become increasingly favorable toward titanium. The demand for lighter weight and/or greater operating efficiencies in all forms of transportation is also likely to continue, and the total potential market of these items is very large. On the basis of these considerations, it appears reasonable to assume that the consumption of titanium mill products in transportation equipment will reach significant proportions by the end of the next decade.

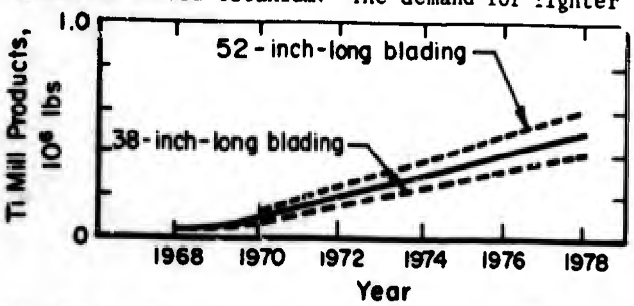

FIGURE 3. PROJECTED CONSUMPTION OF TITANIUM MILL PRODUCTS IN STEAM-TURBINE POWER GENERATORS

A judgment on the quantities of titanium that might be involved is purely speculative. However, it is not unreasonable to expect these requirements to reach a level as high as 500,000 pounds* per year by 1973, and this level may double within the following 5 years, as suggested in Table 4.

Miscellaneous

Miscellaneous applications are here defined as those outside of the specific-use areas described in the preceding paragraphs. These include numerous well-established use items in the general categories of electrochemical and electronic equipment as well as medical prosthesis. Such usage, in 1967, amounted to about 250,000 pounds (see Table 4). Conservatively, the quantity of mill products going into such applications over the next 10 years is expected to increase at a rate of 3 percent per year.

INTEGRATED FUTURE-USE PATTERN

Figure 4 summarizes Table 4 graphically and shows the projected consumption of titanium mill products over the next 10 years in each of the 9 major nonaerospace application areas that were considered separately in this survey.

For the purpose of analysis, these data may also be grouped according to whether they represent an expansion of 1967 applications or whether they represent new future uses. This separation of the data is shown in Figure 5.

As is evident from Figure 5, the DMIC projection suggests that titanium mill-product requirements, based on all existing nonaerospace markets, will increase at an average rate of about 3 percent per year. By the end of 1978, these needs will increase from their current level of 3,250,000 pounds per year to about 4,500,000 pounds per year.

During this same time period, new uses--principally in the areas of desalination, ordnance, transportation, and steam power generation--could give rise to a demand for an additional 5,500,000 pounds of titanium mill products per year. Thus, the total demand for titanium in all nonaerospace applications could rise to a level of about 10,000,000 pounds per year by 1978. Economic factors are overriding in determining how closely these predictions will be achieved.

* This level, for example, could be achieved if 1 million vehicles (10 percent of the current annual automobile production) each required 1/2 pound of titanium.

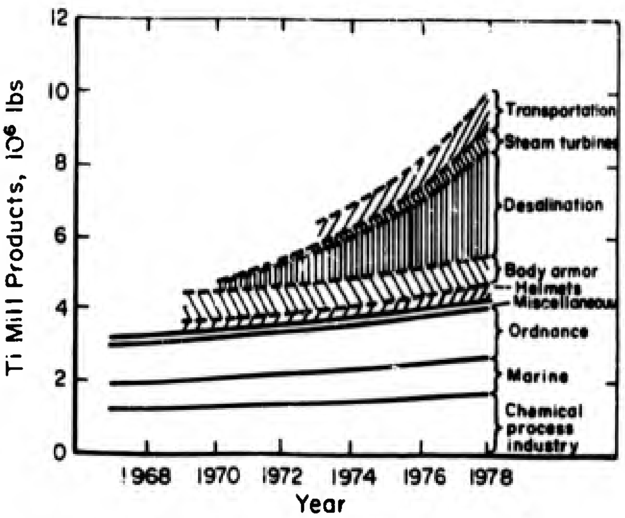

FIGURE 4. PROJECTED CONSUMPTION OF TITANIUM MILL PRODUCTS BY INDIVIDUAL NONAEROSPACE APPLICATIONS

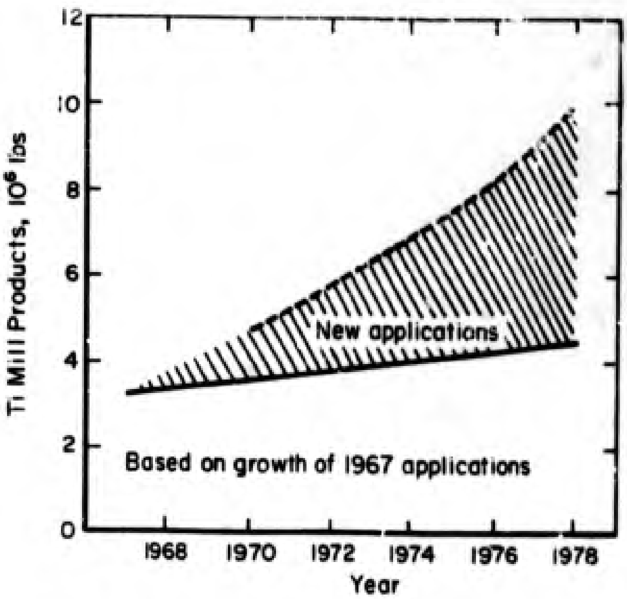

FIGURE 5. PROJECTED CONSUMPTION OF TITANIUM MILL PRODUCTS IN NONAEROSPACE APPLICATIONS

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13. ABSTRACT

This memorandum was prepared at the request of the Titanium Subcommittee of the Materials Advisory Board Committee on Technical Aspects of Critical and Strategic Materials. Current and future use patterns over the next 10 years are surveyed for the following areas of nonaerospace applications of titanium: (1) Chemical and processing industry, (2) Marine and Submarine(3) Ordnance (4) Desalination (5) Electrochemical and (6) Mechanical. Information was obtained from personal discussions with producers and users of titanium, as well as from DMIC files.

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