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ASSIGNMENT OF HIGH PRIORITY TO THE SOVIET TITANIUM INDUSTRY

April 1964

CENTRAL INTELLIGENCE AGENCY

Office of Research and Reports

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Economic Intelligence Report

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ASSIGNMENT OF HIGH PRIORITY TO THE SOVIET TITANIUM INDUSTRY*

Summary and Conclusions

The USSR has assigned high priority to the expansion of production of titanium because of growing requirements and, to a lesser extent, because of the almost complete embargo on shipments of titanium from the Free World to the Communist countries.** Soviet production of titanium sponge*** has increased by about 70 percent since 1958, but in September 1962 a Soviet journal reported that production of titanium "still lagged behind requirements." The uses for titanium include parts for the manufacture of aircraft and space vehicles and for production of corrosion-resisting equipment used in certain chemical processing industries. Because titanium has important strategic applications, exports from the Free World to the Communist countries have been restricted by the Coordinating Committee on Export Control (COCOM).[†]

A probable reason for inadequate Soviet production of titanium is excess generation and underutilization of scrap in the conversion of titanium metal and alloys into mill products.[††] In the USSR in 1963, for example, conversion of 5,000 tons[†††] of titanium sponge into titanium metal and alloys and then into mill products is estimated to have resulted in only 2,800 to 2,900 tons of titanium mill products and a conversion rate of 60 percent -- that is, the tonnage of titanium mill products represented 60 percent of the tonnage of titanium sponge. In comparison, in the US in 1963, conversion of 8,200 tons of titanium sponge resulted in 5,500 tons of titanium mill products and a conversion rate of almost 70 percent. In other recent years, such as 1960 and 1962, the US conversion rate has reached 90 percent.

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* The estimates and conclusions in this report represent the best judgment of this Office as of 1 April 1964.

** The term <u>Communist countries</u> as used throughout this report includes the USSR, Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Rumania, Communist China, North Korea, and North Vietnam.

*** Titanium sponge is raw metal that requires further processing into ingot metal, from which mill products are manufactured.

† In November 1949 a voluntary informal consultative group was organized secretly in Paris to formulate policies and guidelines for the selection of materials to be embargoed multilaterally to the Communist countries. All NATO countries except Iceland joined the group, and a coordinating committee called COCOM was established to carry out day-to-day discussion of items. Subsequent joiners were Japan, Greece, and Turkey, and pledges of cooperation have been received from several neutrals, including Sweden and Switzerland.

†† <u>Polufabrikaty</u> (semifabricates) is the Soviet term that corresponds to the US term <u>mill products</u>.

††† Tonnages are given in metric tons throughout this report.

Another possible explanation is that the shortage of titanium is not general but is confined to selected grades or shapes. The USSR cites technical difficulties in producing high-purity titanium sponge and in controlling contamination in the alloying and melting of ingots and in fabricating higher strength alloys.

Perhaps the problem is administrative as well as technical in that the types of mill products may not be geared properly to requirements. Administrative shortcomings are suggested by the pattern of purchases from Japan. More than two-thirds of the 65 tons of unalloyed titanium products thus far approved by COCOM for Japanese shipment to the USSR has been tubing of exceptionally large diameter, which the USSR does not produce industrially but which it probably could produce with little difficulty.

In any case, Japan is working hard to persuade COCOM to relax the restrictions on shipping "nonstrategic" (unalloyed) titanium products to the Communist countries, largely because of the excess capacity in the Japanese industry that has developed since early 1962, when the US Government stopped buying Japanese titanium. The USSR, however, does not appear to be counting on any significant easement of the embargo.

In the USSR, high priority appears to have been assigned to expanding production of titanium in the economic plan for 1964-65. The plan calls for completion of a second titanium plant, possibly a reflection of Soviet requirements for titanium for missiles and aircraft now being developed. The second plant probably will be in partial operation by 1965, when Soviet production of titanium sponge should reach approximately 6,000 tons per year. By 1970, Soviet capacity probably will be about 10,000 tons, and by 1980 it may be as high as 50,000 tons.

I. Introduction

Development of commercial production of titanium metal after World War II was spearheaded and supported by the US Government in anticipation of large defense requirements for the metal. In 1948 the US became the first country in the world to produce titanium sponge on a commercial basis. From an initial output of about 9 tons in 1948, US production of titanium sponge rose to a peak of nearly 16,000 tons in 1957, and the productive capacity of the US industry reached approximately 25,000 tons per year. 1/* By 1959, however, US production had dropped precipitously to less than 4,000 tons as a result of cancellations of military aircraft (primarily B-52 bombers) and stretchouts leading to the termination of US Government acquisitions for stockpile from domestic producers. After that, US production recovered somewhat and reached a level of 7,200 tons in 1963, primarily because of increased requirements of the programs for missiles, spacecraft, and commercial aircraft and, to a lesser extent, because of increased requirements of the chemical processing industries.

The program of the US in the late 1940's and early 1950's to generate a large output of titanium sponge in a short period of time was instrumental, if not determinant, in encouraging the development of the Japanese titanium industry in the mid-1950's. By 1957, Japanese production had reached 3,100 tons. Much of the Japanese output of titanium sponge has been shipped to the US. During the 7-year period 1955-61, when Japan was shipping titanium to the US under barter contracts with the Commodity Credit Corporation (CCC), Japanese exports to the US averaged about 1,900 tons of titanium per year, all in the form of sponge. 2/ Not all of this metal was exported under barter contract; some was exported on a dutiable basis, and dutiable exports continued in 1962 and 1963. The decline in Japanese output of titanium sponge to 1,500 tons per year in 1962 and 1963 directly reflected the cessation of exports to the US under CCC barter contract in January 1962 and has left Japan with idle capacity. (For data on production of titanium sponge in the Free World, see Table 1.**)

Disappointed in its efforts to expand sales of titanium in Western European markets, Japan became interested in the Communist countries, primarily the USSR, as a potentially large market for its surplus titanium, and the USSR showed interest in buying. In April 1961 the USSR made what is believed to have been its first inquiry into buying Japanese titanium. The USSR indicated that it had planned to buy titanium from the UK but was considering Japanese titanium because of its high quality and low price. The USSR expressed an interest in 200 tons at first and then 600 additional tons. It followed up its inquiries by sending in August 1961 a delegation to tour facilities producing titanium in Japan. 3/ Thus far Japan has obtained

* For serially numbered source references, see Appendix D.
** P. 4, below.

Table 1

Free World: Production of Titanium Sponge Metal a/
1948-63

Thousand Metric Tons

Year	Total b/	US	Japan	UK
1948	Negl.	Negl.	0	0
1949	Negl.	Negl.	0	0
1950	0.1	0.1	0	0
1951	0.4	0.4	0	0
1952	1.0	1.0	Negl.	0
1953	2.1	2.0	0.1	0
1954	5.6	4.9	0.6	0.1
1955	8.2	6.7	1.3	0.3
1956	17.3	13.2	2.5	1.5
1957	20.3	15.6	3.1	1.5
1958	7.0	4.2	1.7	1.2
1959	7.2	3.5	2.5	1.2
1960	8.3	4.8	2.3	1.2
1961	8.9	6.1	2.3	0.5
1962	7.9	6.1	1.5	0.3
1963	9.0	7.2	1.5	0.3

a. 4/. Several other industrialized countries such as Canada, France, and West Germany are believed to produce titanium metal on a laboratory or pilot-scale basis. All of the Japanese and much of the US output of raw titanium metal is in the form of sponge produced by the Kroll method using magnesium as the reductant, whereas all of the UK and a part of the US output of raw titanium metal is in the form of platelets produced by the Kroll method using sodium as the reductant.
b. Because of rounding, components may not add to the totals shown.

permission to sell only small quantities to the USSR as exceptions to the embargo maintained by COCOM on shipments of strategic materials to the Communist countries. Actual shipments from Japan to the USSR have totaled only about 5 tons of titanium mill products with 60 tons more having been approved for export by COCOM in April 1963 for shipment in late 1963 and early 1964.

Japanese requests to sell titanium to the USSR have required intensive analysis of Soviet needs for particular grades and shapes of titanium. The requests also have aroused general interest in the capabilities and intentions of the USSR in the field of titanium.

II. Soviet Production

A. Sponge

Allegedly less convinced than the US of potential requirements for titanium and less willing or able to undertake the large investment necessary to promote a crash program in the development of titanium as a structural metal, 5/ the USSR did not begin production of titanium sponge on an industrial scale until 1954, about 6 years after the US and at about the same time as Japan and the UK. All of the Soviet output of titanium sponge on an industrial scale -- that is, all of the output of the Communist countries on an industrial scale -- is produced at one plant, the Dneprovskiy Titanium-Magnesium Plant in the Ukraine. 6/ Soviet production of sponge is estimated to have increased from 1,000 tons in 1955 to 5,000 in 1962 and 1963, respectively, as shown in the following tabulation 7/:

Year	Thousand Tons	Year	Thousand Tons
1954	Negl.	1959	3.0
1955	1.0	1960	4.0
1956	1.0	1961	4.0
1957	2.0	1962	5.0
1958	3.0	1963	5.0

Nearly all of the Soviet output of raw titanium is sponge produced by the standard Kroll process using magnesium as the reductant, 8/ although the USSR has experimented with sodium as the reductant in production of raw titanium metal. The US uses magnesium and sodium, and Japan uses only magnesium in reducing titanium tetrachloride, the intermediate product, to raw titanium metal. Because the USSR lacks high-quality raw materials such as rutile, the basic material used in the preparation of titanium tetrachloride is either ilmenite concentrate 9/ or slag melted from ilmenite concentrate. 10/ Japan uses slag, whereas the US uses rutile.

The USSR evidently is not able to produce titanium sponge of as high purity as Japan does on a regular basis or as the US is able to do when required. The highest purity sponge that the USSR produces on an industrial basis has a Brinell hardness of between 114 and 118 (the lower the number, the purer the sponge),* whereas the sponge that the US imports from Japan generally has a Brinell hardness ranging between 100 and 105. I.I. Kornilov, a Soviet titanium specialist, during his recent visit to the US is reported to have "lamented" the Soviet lack of high-purity titanium sponge for programs in research

* For Soviet specifications for titanium sponge, see Appendix A.

and alloy development. 11/ More specifically, other Soviet sources recently have stated that the requirements for high-purity sponge had risen in connection with the development of new heat-resistant refractory alloys 12/ and that the output of high-purity sponge must be increased significantly. 13/ A more basic problem that may not be completely resolved is the standardization of the Kroll process for production of titanium sponge of more uniform quality. 14/ In 1962, perhaps in response to both problems, the USSR established a new specification series for titanium sponge, which is at once broader and more precise than the one for 1958 (believed to have been the second official Soviet specification series for titanium sponge).*

B. Metal

1. Melting Processes

Most of the Soviet industrial output of titanium metal and alloys (including the VT, OT, and AT series) constitutes ingots produced from titanium sponge in consumable-electrode vacuum-arc furnaces. 15/ Titanium produced in this manner is particularly suited for rolling, the basic fabricating technique used for the metal at present. Induction melting is used for shaped castings and for the preparation of alloys for small forgings and stampings. 16/ Induction melting is alleged to have one advantage over vacuum-arc melting -- production of more homogeneous ingots -- but the ingots suffer from carbon contamination and are limited to a weight of about 200 kilograms. 17/ To produce flatter, broader ingots that are more suitable for rolling than the bar-shaped ingots of vacuum-arc melting, the USSR has worked with the electroslag remelting process and in 1958-59 prepared experimental ingots weighing up to half a ton. 18/

One limitation of the Soviet vacuum-arc furnaces is the relatively small size of ingots that they can melt. Not until 1958 did the USSR develop and use consumable-electrode vacuum-arc furnaces capable of producing 1-ton ingots on an industrial scale. 19/ By 1958, some US companies were producing ingots weighing about 4 tons. By 1961, furnaces capable of producing ingots weighing up to 2 tons were being operated on an experimental basis in the USSR, 20/ and the development of a furnace capable of producing ingots weighing up to 5 tons was announced in 1962. 21/ During his recent trip to the US, Kornilov is reported to have said that the "usual" weight of Soviet titanium ingots is 2 to 3 tons. 22/ Most final titanium ingots produced in the US at present are larger, weighing between 3 and 5 tons. Among the disadvantages presented by the smaller size of Soviet titanium ingots are greater scrap generation in fabricating and greater limitation in the length and width of titanium sheet and plate that can be rolled.

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* For a comparison of the two latest Soviet specification series for titanium sponge, see Appendix A.

2. Iodide Process

For research purposes (particularly those requiring high-purity metal -- for example, the development of high-strength alloys that can be heat-treated), the USSR uses the iodide process to produce on a laboratory scale titanium having a purity of about 99.95 percent. 23/ In 1957 the USSR reported having made "superpure" titanium with a purity of 99.98 percent. 24/ "Superpure" titanium is believed to be iodide titanium that has been subjected to zone refining, a process described recently in Soviet publications. 25/

3. Electrolysis

The broad Soviet effort in mastering the economic production of titanium metal has included a large volume of experimental work in various electrolytic processes. Some of the work has been directed to the purification of scrap 26/ and much to the preparation of primary titanium metal from titanium sponge and compounds. 27/ The USSR has claimed that titanium is to be produced by electrolysis in the new plant under construction at Ust'-Kamenogorsk. 28/

4. Powder Metallurgy

One of the most original and successful Soviet efforts in titanium is the use of powder metallurgical techniques. The USSR originally turned to powder metallurgy as a means of producing titanium metal with better mechanical properties than that produced from titanium sponge by induction melting. According to a Soviet source, the mastery of the melting of ingots in consumable-electrode vacuum-arc furnaces destroyed this particular advantage. 29/ The major limitation of powder metallurgy is the relatively small weight -- up to 80 kilograms -- of the compacted (sintered) billets. With the wider use of vacuum-arc furnaces the importance of powder metallurgy may have diminished somewhat. 30/ Using the calcium hydride method, the USSR produces the IMP (and perhaps the T) alloy series; the purest powder of the first series, IMP1A, contains at least 99.66 percent titanium.

C. Alloys

The USSR began its systematic study of titanium-base alloys in 1956, 31/ somewhat later than the US, but has developed a larger number of titanium alloys than the US. A US study, however, concludes that the Soviet development of a larger number of alloys was promoted by a lack of suitable melting and fabricating equipment in the USSR. These alloys generally are not as strong as US alloys, strength having been sacrificed in making the alloys easier to fabricate. 32/ Of the more than 50 titanium alloys produced in the USSR that have been described in Soviet publications, only the following 14 were in series production in 1963: VT1, VT3, VT3-1, VT4, OT4, OT4-1, VT5, VT5-1, VT6, VT8, VT9, VT10, VT14, and VT15. 33/ VT14 and VT15 also are referred to as being "experimental" alloys. The composition of this particular grouping, especially when the inclusion of VT14 and VT15 is doubtful, confirms the conclusion that the USSR has not yet mastered commercial production of high-strength titanium alloys that can be heat-treated 34/ and that would be useful in some aircraft and aerospace applications. Hydrogen contamination in the fabricating (rolling) of the stronger "experimental" alloys such as VT14, VT15, and VT16 is resulting in problems of embrittlement not encountered earlier in the fabrication of weaker alloys.* 35/

D. Mill Products

Soviet reports tell of excessive generation of scrap during production of titanium mill products from titanium metal and alloys and of less extensive reclamation of such scrap compared with US practice. These reports indicate that the USSR has to use more titanium sponge per unit of mill product than does the US. During the 3 years 1960-62, about 35 percent of US consumption of ingots became scrap in production of mill products compared with 50 percent of the metallurgical charge used in the melting of ingots in the USSR. 36/ During the same period the US used 30 percent scrap in the melting of ingots. Although the USSR has claimed that it is possible to use charges containing 20 to 40 percent scrap in the melting of ingots, 37/ a more recent Soviet source indicates that the USSR uses charges containing only 10 to 15 percent scrap in the melting of ingots. 38/ On the basis of consumption of about 5,000 tons of sponge, a scrap generation rate of 50 percent, and a scrap utilization rate of 10 to 15 percent, the Soviet output of mill products in 1963 is estimated to have been approximately 2,800 to 2,900 tons.** In the same year the US consumed 8,200 tons of titanium sponge and produced 5,500 tons of mill products. For the estimated Soviet consumption of sponge and output of titanium mill products in 1963 and earlier years, see Table 2.***

III. Soviet Uses

Most of the US output of titanium is used in strategic applications. In 1962, for example, 60 percent of the total US titanium mill products purchased was for military aircraft, 25 percent for missiles and space exploration, 10 percent for commercial aircraft, and the remaining 5 percent for applications where the resistance of the metal to corrosion was the major consideration. Except for general statements -- for example, that the use of titanium has great significance in aviation and rocket engineering, in the preparation of "cosmic" apparatus, in ship sheathing, and in various civilian industries -- the USSR has not revealed a use pattern for its consumption of titanium.

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* For a more complete listing of Soviet titanium alloys, their compositions, and some of their characteristics, see Appendix B.

** Addition of alloying ingredients, however, probably made the output of Soviet mill products somewhat higher.

*** For a listing and description of selected Soviet titanium mill products, see Appendix C.

Table 2

USSR: Consumption of Titanium Sponge Metal
and Output of Titanium Mill Products
1955 and 1958-63

Thousand Metric Tons

Year	Consumption of Sponge a/	Output of Mill Products
1955	1.0	0.6
1958	3.0	1.7
1959	3.0	1.7
1960	4.0	2.2 to 2.3
1961	4.0	2.2 to 2.3
1962	5.0	2.8 to 2.9
1963	5.0	2.8 to 2.9

a. For each year, consumption of titanium sponge metal is estimated to have equaled estimated production of titanium sponge metal.

Although the USSR also probably uses a large part of its titanium in strategic applications, the only documentary evidence (beyond many technical articles on titanium published by men associated with the All-Union Scientific Research Institute of Aviation Materials -- VIAM) possibly supporting this conclusion is the following statement in a Soviet book on the welding of light alloys that was published in 1960: "At the present time the chief consumer of titanium is the aviation industry." 39/ This reference, however, does not indicate where this is true and may just be another description of a situation in the Free World. Dramatic and direct evidence of Soviet consumption of titanium in a strategic application is a fragment of a Soviet space vehicle found in Pretoria, South Africa, in May 1963. This fragment has been determined to consist of "a flat sheet of titanium alloy brazed to a corrugated sheet of commercially pure titanium." 40/ The particular characteristic of titanium that makes it suitable for aircraft and spacecraft applications is its favorably high ratio of strength to weight coupled with a moderate resistance to heat.

Although the USSR may consume most of its titanium in direct and indirect military applications, the limited discussion of consumption of titanium in Soviet publications deals mostly with actual and potential essentially civilian applications. For example, the USSR has stressed the particular value of titanium for equipment in chemical, oil, food, textile, power, and nonferrous metallurgical enterprises, primarily because of the unique corrosion resisting properties of the metal. 41/ Production of reactors, separators, filtering units, and heat exchangers made of titanium has been claimed for a number of years.

Consumption of titanium appears to have been increasing in the USSR in recent years as uses of the metal have entered new fields beyond those strictly military in nature. The statement in a Soviet journal in early 1962 that "Recently, there has been a marked expansion in the use of titanium in both shipbuilding and chemical machinery construction" illustrates the trend. 42/ A civilian application of titanium in chemical machinery that has received particular emphasis in the Soviet press during the past 2 years is its use in equipment such as pumps, shutoff valves, autoclaves, and cathodes for production of nickel. 43/ In this connection a recent Soviet achievement was the development of a series of prototypes for four pumps made of the commercially pure titanium VT1, with flows of 30, 50, 200, and 400 cubic meters per hour. 44/ Experimental production of the 200-cubic-meter pump was carried out at the Severonikel' Combine in Monchegorsk during 1959-62, and by late 1962 more than 100 pumps were reported to have been manufactured there. Series production of the pump was planned to begin at the Shchelkovo Pump Plant in 1962 but had failed to get underway by November of that year. 45/

Although the Soviet press has given a rather one-sided emphasis to civilian applications of titanium, there are no specific indications that the USSR is using or contemplating more extensive use of titanium in such applications than the US. The most significant civilian consumer for titanium in both countries at present, with the exception of civilian aircraft, appears to be chemical processing equipment used by various industries. Soviet applications of titanium in equipment of this type as described above are like those of the US. Chemical processing equipment made from titanium used in the US includes heat exchangers, tubing, pumps, and cathodes for use in enterprises that produce nickel, cobalt, manganese, acetaldehyde, pulp and paper, and certain other materials. 46/

Because of its high cost the selection of titanium as the material to be used in civilian applications in both the USSR and the US appears to be based on approximately the criteria that govern its selection in military applications -- that is, weight savings, longer life, and lower operating costs. 47/ For example, a US company recently advertised a titanium chlorine cell which cost $1,200 and which would operate effectively for 2 years. The titanium chlorine cell could be a replacement for a stainless steel cell which cost $800 but which would need to be replaced every 3 months. 48/ Similarly a Soviet source recently described a titanium cathode 2.25 times more expensive than a stainless steel cathode but capable of replacing 28 or 29 stainless steel cathodes. 49/

IV. Soviet Requirements Compared with Supply

In September 1962 a Soviet journal reported that production of titanium "still lagged behind requirements," although the same article stated that the plan for the first half of 1962 had been exceeded. 50/ The lag behind requirements probably is attributable, at least in part, to the losses sustained in converting titanium sponge to ingots and then to mill products and fabricated items. During 1960-63, Soviet consumption of sponge averaged about 72 percent of US consumption, whereas Soviet production of mill products was only half that of the US. If Soviet production of mill products were almost 50 percent larger, as would be the case if the Soviet conversion rate from sponge to mill products were the same as the US rate, the supply of mill products might be adequate.

The USSR, however, may be having qualitative as well as quantitative problems. The USSR may be having difficulty in meshing production and delivery of particular shapes or grades of titanium mill products. For example, the USSR placed an order for 60 tons of unalloyed titanium tubing with Japan in mid-1962, soon after the publication of a Soviet statement that "recently there has been a considerable increase in demand for tubes made of titanium and its alloys." 51/ Moreover, 46 tons constituted tubing of unusually large diameters, 300 and 400 millimeters (mm), or about 12 and 16 inches, respectively, 52/ which the USSR does not produce on an industrial scale but which should present no great problems. (Unalloyed tubing of such dimensions apparently is not used in the US either industrially or militarily, but Japan indicated during the negotiations that the Soviet intention of using large quantities of such tubing in the construction of a plant producing acetaldehyde was in accord with Japanese practice.) The USSR does manufacture some titanium tubing on an industrial basis, but the diameter is not believed to exceed 130 mm (about 5 inches). In 1962, however, the USSR did report experimental production of tubing with a diameter of 325 mm (about 13 inches) for use in autoclaves for oxidation leaching of sulfide nickel solutions.* 53/

In any case, shortages of titanium in the USSR do not appear to be related to Soviet shipments of titanium to Cuba. As was bruited about widely in the Western press, the USSR has supplied Cuba with titanium tubing as well as sheet for repairing equipment at the Moa Bay Nickel Plant. The total shipped by the USSR is believed to have been so small and to have been composed of such ordinary products that these shipments alone could not have imposed undue or prolonged strain on the internal Soviet supply of titanium mill products. If titanium of Japanese origin was diverted from the USSR to Cuba, it came out of the first major exception granted to Japan by COCOM in

* For a discussion of other qualitative difficulties such as the Soviet lack of high-purity titanium sponge and contamination difficulties encountered in making and fabricating some titanium alloys, see II, p. 5, above.

early 1962 for 5 tons of assorted mill products, which were reported to have been shipped to the USSR during June-August 1962. Titanium tubing of various diameters made up 2 tons of this transaction, one-half ton of which was of rather large diameter (200 mm, or about 8 inches). 54/

V. Outlook

Although the quantity of titanium required throughout the world has been increasing along with proliferations in its applications, titanium still cannot be called a common structural metal and remains a "metal of the future." In the early 1950's, some US experts forecast annual requirements for titanium of about 100,000 tons by the 1960's in the US alone, but world output of some 14,000 tons of titanium sponge in 1963 demonstrated the prematurity of that prediction. In the early 1960's, however, spokesmen of US industry remain optimistic about the future of titanium and have forecast a US output of some 16,000 to 22,000 tons of mill products by 1970 (compared with less than 6,000 tons in 1963) and a US market for 110,000 to 230,000 tons of titanium mill products by 1980. 55/ Although not specifying what its requirements are today or one day might be, the USSR does not dispute the likelihood of much larger requirements for titanium at some future date. A recent Soviet publication noted that world requirements of some 200,000 tons annually may be expected. 56/ Another publication has stated that production of titanium and its alloys in the future "must" approach that of stainless steel. 57/ In recent years the US has been producing more than 1 million tons of stainless steel annually, and Soviet output is estimated to range between 300,000 and 500,000 tons annually.

For several reasons, there can be little doubt that the expected increase in requirements for titanium will materialize ultimately. Titanium embodies properties that are very useful for the space age -- for example, it possesses an extremely high ratio of strength to weight at moderate temperatures, which gives it a distinct advantage over both steel, which is heavier, and lighter metals such as aluminum and magnesium, which are not as strong. High-purity titanium metal has a unique toughness at very low temperatures, a characteristic that currently is being publicized. Competent technology for recovering the metal from its ores and for transforming it into products has already been highly developed, and so increasing requirements for the metal can be expected to lower its present high cost considerably. The abundance of titanium-bearing ores makes high-volume production feasible, and its wider use, therefore, may be encouraged.

A most promising area for a substantial breakthrough to increased requirements for titanium in the near future in the US and probably in the USSR as well would be commercial production of the supersonic transport airplanes being developed in both the US and the USSR. Within the upper limitation of titanium, the faster the airplane is designed to fly, the higher are its expected requirements for titanium. Depending on its speed, it has been estimated that the US version will require from 15 to 50 tons of titanium mill products per unit. At present the US is leaning toward the selection of a design for a supersonic transport that would fly at a speed of Mach 2.7 or Mach 3, which requires that titanium be the basic structural material. 58/ On the other hand, the supersonic transport that the USSR is developing reportedly is to have a speed ranging between Mach 2.2 and Mach 2.4. 59/ Although such a transport would include some titanium in "hot spots," the major structural material used would be aluminum, the basic material to be used in the British-French supersonic transport, the Concorde, which is to fly at speeds up to Mach 2.2. 60/ The USSR, however, possibly is working on the development of fighter aircraft that are intended to have speeds of about Mach 3. Titanium would be a major structural metal used in such airplanes, as it is in the secretly developed US Mach 3 A-11 interceptor whose existence was revealed recently by President Johnson.

Both the US and the USSR are making efforts to insure that sufficient titanium is available to meet expected increases in requirements. In the US the Office of Emergency Planning (OEP) has begun to consider the reestablishment of a strategic stockpile objective for titanium. 61/

In the USSR, increasing the supply of titanium has been an important objective since the late 1950's. The Soviet Seven Year Plan (1959-65) calls for an increase in production of titanium at least double that of 1958. 62/ Achievement of this goal, estimated at 6,000 tons of titanium sponge in 1965, depends on whether or not the new titanium-magnesium combine now under construction at Ust'-Kamenogorsk in Kazakh SSR comes into operation on schedule. At present, achievement of this goal seems likely. In December 1963, P.F. Lomako, Chairman of the State Planning Committee, specifically noted that a substantial growth in the Soviet production of titanium was planned for 1964-65 and that the first parts of the Ust'-Kamenogorsk Titanium-Magnesium Combine would come into operation during the 2-year period. 63/ Moreover, the combine is reported to have produced its first sponge metal in March 1963 in an experimental shop. 64/ It is believed that, when in full operation, which should be the case by 1970, this combine will have a capacity of at least 5,000 tons of sponge -- that is, as large as or larger than that of the Dneprovskiy Titanium-Magnesium Plant in the Ukrainian SSR. Development of the titanium industry in the RSFSR also is being planned, apparently within the framework of the Soviet Twenty Year Plan, which calls for the construction of plants in East Siberia that are to have an estimated annual output of some 40,000 tons of sponge by 1975 or 1980. 65/ Therefore, if these plants in the RSFSR materialize, total Soviet capacity for production of titanium sponge would be approximately 50,000 tons per year by 1980.

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APPENDIX A

USSR: SPECIFICATIONS FOR TITANIUM SPONGE METAL a/ 1958 AND 1962

Designation	Brinell Hardness b/	Maximum Content of Admixtures (Percent)					
		Fe	Si	C	Cl	N	O
Tu TsMZ 2-01-58 c/							
TG00	115	0.15	0.05	0.05	0.06	0.03	0.10
TG0	145	0.15	0.05	0.05	0.06	0.03	0.10
TG1	165	0.30	0.10	0.06	0.08	0.05	0.20
TG2	185	0.30	0.10	0.06	0.10	0.06	0.20
MRTU 14 No 1-62 d/							
TG118	114 to 118	0.12	0.05	0.04	0.06	0.03	0.07
TG130	119 to 139	0.15	0.05	0.04	0.08	0.03	0.09
TG140	131 to 140	0.15	0.05	0.05	0.08	0.03	0.11
TG155	141 to 155	0.25	0.08	0.06	0.10	0.04	0.13
TG170	156 to 170	0.25	0.08	0.06	0.10	0.05	N.A.
TG190	171 to 190	0.30	0.10	0.06	0.12	0.06	N.A.
TGChM	191 or more	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
TG1130P e/	113 or less	0.10	0.05	0.03	0.06	0.03	0.06

a. TsMTU 4776-56 is believed to have been the first Soviet specification series and was composed of TG0 and TG1-3. 66/

b. The harder the titanium sponge, the higher its Brinell number and the greater its contamination.

c. Designations for 1958. TG00 was intended only for research, and the remaining three were for use in the melting of alloys. 67/

d. Designations for 1962. 68/

e. "OP" probably is an abbreviation for "experimental."

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APPENDIX B

USSR: TITANIUM ALLOYS

Designation	Average Content of Major Alloying Ingredients (Percent)	Remarks
Alloys in use in 1961 a/*		
VT1-1	Commercial titanium	99.25 percent Ti
VT1-2	Commercial titanium	
VT3 b/c/	5.5 Al, 3.5 Cr	Forging alloy for use at temperatures up to 350°C. According to Tsvetnyye metally, this is a high-temperature alloy capable of enduring temperatures up to 700°C for prolonged periods and even higher for brief periods. d/
VT3-1 b/c/	6.5 Al, 2 Mo, 2 Cr, 1 Fe	Forging alloy for use at temperatures up to 350°C. According to Tsvetnyye metally, this is a high-temperature alloy capable of enduring temperatures up to 700°C for prolonged periods and even higher for brief periods. d/
VT4 b/c/	4 Al, 1.5 Mn	Rolling alloy for use at temperatures up to 450°C.
VT5 b/c/	5 Al	Forging alloy for use at temperatures up to 350° to 450°C.
VT5-1 b/c/	5 Al, 2.5 Sn	
VT6 b/c/	6 Al, 4 V	Forging alloy for use in temperatures up to 350° to 400°C.
VT8 c/	6.5 Al, 3.5 Mo, 0.25 Si	Forging alloy for use at temperatures up to 500° to 550°C.

* Footnotes follow on p. 21, below.

Designation	Average Content of Major Alloying Ingredients (Percent)	Remarks
VT10 c/e/	5 Al, 2.5 Sn, 3 Cu	For use at temperatures up to 500°C and, according to Tsvetnyye metally, d/ for use at temperatures up to 700°C.
VT12 e/	4 Al, 0.8 Mo, 3 Sn, 2 Zr	
VT14 c/	4 Al, 3 Mo, 1 V	
VT15 c/e/	3 Al, 8 Mo, 11 Cr	
OT4 b/c/	3 Al, 1.5 Mn	Rolling alloy for use at temperatures up to 400° to 450°C.
OT4-1 b/c/	2 Al, 1.5 Mn	Rolling alloy.
OT4-2 b/e/	6 Al, 1.5 Mn	
AT3 e/	3 Al, 1.5 (Cr + Fe + Si + B)	For use at temperatures up to 400° to 450°C.
AT4 e/	4 Al, 1.5 (Cr + Fe + Si + B)	
AT6 e/	6 Al, 1.5 (Cr + Fe + Si + B)	For use at temperatures up to 500°C.
IRM2 e/	5.5 Al, 4.5 Nb, 0.15 Re	
2Al	2.5 Al	
3Al	3.5 Al	
Al-Zr	3 Al, 2.5 Zr	
3-11 e/	3 Al, 11 Sn	
4-6-2 e/	4 Al, 6 Sn, 2 Cu	

Designation	Average Content of Major Alloying Ingredients (Percent)	Remarks
Other alloys as of 1963		
VT1 c/	Commercial titanium	Rolling stock for use at temperatures up to 400° to 450°C.
VT1D	Commercial titanium	
VT2	1 to 2 Al, 2 to 3 Cr	
VT2D	2 to 6 Al, up to 3 Cr	
VT5D	N.A.	
VT7	4.5 to 6.0 Al, 3.5 to 4.5 V, 0.15 to 0.4 Si, 0.3 to 1.1 Fe	
VT9 c/	5.8 to 6.8 Al, 2.8 to 3.8 Mo, 1.8 to 2.8 Sn, 0.2 to 0.4 Si	According to Tsvetnyye metally, d/ for use at temperatures up to 700°C.
VT14-1	N.A.	
VT16	N.A.	
48T3	3.5 to 4 Al	
48T4	4 Al	
48T5	5 Al	
48T7	Al, Zr	Perhaps the same as Al-Zr, mentioned above.
AT2	N.A.	
AT2-1	N.A.	
AT2-2	N.A.	
AT2-4	N.A.	

Designation	Average Content of Major Alloying Ingredients (Percent)	Remarks
AT8	6.5 to 8.0 Al, 1.0 to 1.8 (Cr + Fe + Si + B)	For use at temperatures up to 550°C.
AT9	N.A.	
AT10	N.A.	For use at temperatures up to 650° to 700°C. f/
AT12	N.A.	For use at temperatures up to 650° to 700°C. f/
T2	2 to 3 Al	
T3	3 to 4 Al, Cr, Fe, Si, B	Perhaps the same as AT3, mentioned above.
T4	4.77 Al, 1.70 (Cr + Fe + Si + B)	Perhaps the same as AT4, mentioned above.
T5	4 to 5 Al, 2 to 3 Cr	
T6	Al, Cr, Fe, Si, B	Perhaps the same as AT6, mentioned above.
T7	2.0 Al	
T8	Al, Cr, Fe, Si, B	Perhaps the same as AT8, mentioned above.
TG8	8 Mn	Perhaps a manganese-containing sponge.
IMP1	N.A.	Powder alloy.
IMP1A	Commercial titanium	99.66 percent Ti powder.
IMP2	Up to 5 Cr	Powder alloy.
IMP3	Cr	Powder alloy.
IMP6-1	3 Fe, 3 Mn, 3 Cr	Powder alloy.

Designation	Average Content of Major Alloying Ingredients (Percent)	Remarks
IMP6-2	5 Cr, 3 Al, 3 Fe	Powder alloy.
IMP7	5 Al, 3 Mo, 3 V, 1 Zr	Powder alloy.
IMP8	3 Sn, 1.5 Al	Powder alloy.
IMP9	4 Al, 2 V	Powder alloy.
IMP10	13 V, 11 Cr, 3 Al	Powder alloy.
IRM1	4 Al, 4 Nb	
IRM3	4 Al, 3.5 Mo	
IRM4	3.5 Al, 3.5 Mo, 0.1 Re	
IRM6	4 Al, 4.5 Fe	
IRM7	5 Al, 3 Mo, 3 V, 1 Zr	

a. 69/
b. In a Soviet book on aviation metalworking published in 1962 by the defense publishing house, this alloy was singled out as being used in the USSR. 70/
c. This alloy was reported in 1963 to be in series production. 71/
d. 72/
e. Experimental alloy, according to source 73/.
f. 74/

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APPENDIX C

USSR: CHARACTERISTICS OF SELECTED TITANIUM MILL PRODUCTS

	Millimeters				
Mill Product	Thickness a/*	Diameter	Length	Width	Material
Sheet	0.5 to 6.0		1,500 to 2,500 and longer	600 to 1,000	VT1, VT4, OT4, OT4-1, VT5-1, VT6, VT14, VT15
Forged rods and round and square wire bars		15 to 200	600 to 1,400		VT1, VT3, VT3-1, OT4, VT4, VT5, VT6, OT4-1, VT5-1, VT7, VT8
Pipes and tubes	30 to 40	90-to-130 exterior and 25-to-70 interior			VT1, OT4, OT4-1
	12 to 20	82 to 146			VT1D
	6	102	Up to 5,500		Commercial grade
	5	89	Up to 5,500		Commercial grade
	2 to 8	8 to 62	2 to 7		VT1, VT5
	1 to 2	12, 16, 25, 38, 76			VT1
	0.8	42			VT1-1, OT4, VT5-1
	4.5 b/	57 b/	Up to 13 b/		

* Footnotes follow on p. 24, below.

Mill Product	Millimeters				Material
	Thickness a/	Diameter	Length	Width	
Pipes and tubes (Continued)	2.5 to 7.5	32 to 50	960 to 2,260		Powder
	1.0 to 2.4	22 to 34.5	1,500 to 6,000		Powder
Tube liners for steel pipe		115	600 to 800		VT1
Welding wire		1.2 to 7			VT1, VT5, OT4
Wire		0.01			VT1, VT5
Pressed profiles		15 to 86			VT1, VT3, VT3-1, VT5-1, VT4, OT4, VT6
Strip	0.6			200	VT1-2, VT4, OT4
Plate	12 to 16			1,000	VT3, VT3-1, VT8
Shape-rolled					VT5
Stampings					VT3, VT3-1, OT4, VT6, VT8

a. Wall thickness is given for pipe and tubes.
b. Experimental work in Czechoslovakia.

APPENDIX D

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