Appendix C

Overview of Second-Tier Materials

Bauxite and alumina are the raw and semi-processed materials from which aluminum is made. They are considered to be strategic materials because of the high U.S. import reliance and because of the size and importance of the aluminum industry. For several reasons, however, bauxite and alumina are not in the first tier of strategic importance: many of the end uses of aluminum are not highly critical and can easily be replaced by substitute materials; the sources of bauxite and alumina supply are fairly diverse and relatively reliable; and, since the United States is the world's largest aluminum producer, accounting for 25 percent of the world's production of aluminum, the U.S. market is very important to foreign suppliers.

Alumina (aluminum oxide) is produced from bauxite, and it is made into aluminum for use in products such as alloys, chemicals, and abrasives, Aluminum alloys offer widely varying combinations of mechanical strength, ductility, electrical conductivity, and corrosion resistance. Some alloys have strengths approaching those of steel. Similar to most other materials, the worldwide recession caused declines in the consumption of bauxite and alumina in 1982 (see table C-l).

Containers and packaging account for over 20 percent of total aluminum consumption and are the largest end use for the material. Almost as large is the amount used in construction, for such products as residential siding, doors and windows, roofing, mobile homes, curtain walls, bridge rails, and guard rails. The automobile industry accounts for about 10 percent of U.S. aluminum consumption for such items as body, brakes, steering, pistons, trim, electrical uses, and metallic paint. Other transportation uses—marine vessels, rail cars, military vehicles, aircraft, and recreational vehicles—account for another 10 percent of consumption. Aluminum cable with steel reinforcing has replaced copper for high-capacity electrical transmission lines. This and other electrical uses account for still another 10 percent of the aluminum used in the United States,

Table C-1.–U.S. Consumption of Bauxite, 1978-82

Year	Apparent consumption (thousand metric dry tons)
1978	5,300
1979	5,106
1980	5,824
1981	5,555
1982	4,048

SOURCE: U.S. Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984.*

Approximately 10 percent of U.S. bauxite consumption goes into nonmetallic applications. Aluminous chemicals are used for water and sewage treatment, dyeing, leather tanning, and sizing paper. Bauxite is also used in high-alumina cement, as an absorbent or catalyst by the oil industry, in welding rod coatings, and in fluxes for steelmaking. High-alumina abrasives and refractories are used in glass and ceramic products.

For many of the important uses of aluminum there are adequate substitutes; e.g., steel and wood can be used in residential construction. Zinc-based diecastings and chromium-plated steel were replaced by aluminum in the automobile industry, and a shortage of aluminum could conceivably reverse this substitution. Copper can be used in electrical applications, and glass, plastics, paper, and steel can be used in packaging. For some transportation uses, magnesium and titanium can be used instead of aluminum, albeit at significantly increased costs.

Approximately 97 percent of U.S. bauxite supplies come from Jamaica, Guinea, and Suriname. Alumina is imported from Australia, Jamaica, and Suriname. Australia is the world's largest producer of bauxite. As table C-2 shows, many other countries have large reserves and production capacities of bauxite; e.g., Brazil, India, Guyana, Greece, and Yugoslavia. Thus, there is a wide diversity of world suppliers, each with large reserves.

The United States is the world's largest producer of aluminum and therefore the world's largest market for bauxite. It appears unlikely that raw materials producers would refuse sales to this country, lest they risk losing their share of this rich market.

The United States has a small bauxite mining industry, but reserves are relatively limited. The Bureau of Mines has conducted research on producing alumina from alternative materials such as clays, alunite (a potassium-aluminum-sulfur mineral), coal wastes, and oil shales, The United States has large resources of these materials and could meet most of its aluminum raw materials needs if the appropriate technology were developed. A private industry consortium, Alumet, has done work on producing alumina from domestic alunite. A large deposit of alunite discovered in Utah in 1970 could supply domestic aluminum producers for

Table C-2.—Bauxite: U.S. Imports, World Production, and Reserves

Sources of U.S. imports (1979.82):

Country	Percent
Jamaica	39
Guinea	32
Suriname	10

NOTE: 1982 U.S. net import reliance = 96 percent.

World mine production and reserves, 1982 (thousand metric dry tons):

	Mine production		Reserves	
Country	Amount	Percent	Amount	Percent
Australia	23,621	32	4,600,000	21
Guinea	10,908	15	5,900,000	26
Jamaica	8,380	11	2,000,000	9
Brazil	4,186	6	2,300,000	10
Soviet Union	4,600	6	300,000	1
Greece	2,853	4	650,000	3
Yugoslavia	3,668	5	400,000	2
Hungary	2,627	4	300,000	1
Suriname	3,059	4	600,000	3
India	1,854	2	1,200,000	5
Guyana	953	1	900,000	4
United States	732	1	40,000	<1
Other market economy countries	4,820	6	3,100,000	14
Other central economy countries	2,180	3	200,000	1
World total	74,441	100	22,500,000	100

SOURCE:U.S. Department of the Interior, Bureau of Mines,*Mineral Commodity Summaries 1984.*

years. But alunite is a lower grade alumina raw material than bauxite, and the processing is currently more expensive than the standard Bayer process used on bauxite. Although the technology is available (the Soviets are now producing alumina from alunite), it it uneconomic in the United States at this time.

Beryllium is the second tier because of its critical end uses and because one U.S. company is the sole processor of raw ore for beryllium in the entire free market world. Because of its relatively high price, use of beryllium is not widespread. But where it is used, it appears to be highly critical, especially to defense. Arguing against a higher strategic rank for beryllium is the fact that the United States is apparently capable of supplying most of its own needs. (U.S. production figures are not available, so this conclusion is not certain.) Also, beryllium is used in relatively small amounts, so transportation of imports is not a significant problem.

Forty percent of U.S. beryllium consumption goes to the aerospace industry and to nuclear weapons. Although the details of the military uses of beryllium are classified, beryllium is known to be a particularly good reflector of neutrons, Known aerospace applications have been in missiles, aircraft brake disks, aircraft frames, satellites and space vehicles, and inertial navigational systems for missiles and aircraft. Another large application (35 percent of consumption) is in beryllium-copper alloys in electronic components, including high-strength, noncorrosive housings for underwater cable repeater stations, contacts, and heat sinks, A relatively new use is in ceramic beryllium oxide substrates for complex electronic circuitry.

Consumption patterns of beryllium reflect its defense and aerospace uses. Table C-3 shows that consumption has actually been increasing, even in hard times.

Beryllium's special properties include light weight, high strength, high thermal conductivity, and neutron moderating and reflecting capability. There are some substitutes for beryllium metal (steel, titanium, graphite composites) and beryllium-

Table C-3.–U.S. Consumption of Beryllium, 1978-82

Year	Apparent consumption (short tons)
1978	271
1979	303
1980	321
1981	303
1982	150

SOURCE: U.S. Department of the Interior, Bureau of Mines,*Mineral Commodity Summaries 1984* copper alloys (phospher bronze), but not without a substantial loss of performance. Synthetic sapphire can be used in place of beryllium in some electronic uses.

Some beryllium ores are imported, but exact figures for net import reliance are not available because domestic production data are withheld to avoid disclosing company proprietary data (see table C-4). Before 1969, the United States was over 90 percent import-dependent. In that year, a domestic plant opened to convert imported and domestic beryl and bertrandite to to beryllium oxide. This plant is the only known ore processing facility in the market economy countries. It appears that the United States is capable of meeting its own beryllium requirements to a substantial degree, U.S. reserves are very large (28,000 tons) in relation to the 1982 consumption of 328 tons, and reported imports for 1982 were moderate—108 tons. Also, in the case of beryllium, distance from sources of supply is not an important factor. Because the material is used in relatively small quantities, it could be airlifted if necessary.

Columbium (niobium)[1] is included as a second-tier strategic material because it is entirely imported—mostly from a single source, Brazil—and because it is used in a variety of essential industries. It is not in the first tier, however, because there are a number of substitute materials. Also, it is used in limited quantities and could be airlifted from foreign suppliers if necessary. Table C-5 shows a trend of increased use of columbium, except for the recession year of 1982.

High-strength, low-alloy (HSLA) steels owe their strength and toughness in part to a fine-grained structure. Columbium is used in HSLA's at levels ranging from 0,01 to 0.04 percent by weight to help attain this structure. With the trend toward more use of HSLA steels to replace plain carbon steels, consumption of columbium has increased. The addition of ferro- and nickel-columbium to high-temperature superalloy imparts strength and carbide stability. For stainless steels, too, columbium provides carbide stability.' There are substitutes for columbium, but not without performance penalties; vanadium and molybdenum in HSLA steels; tantalum and titanium in stainless and high-strength steel and superalloys; molybdenum, tungsten, tantalum, and ceramics in high-temperature applica-

[1]Columbium and niobium are two names for the same metal. The name columbium is favored by engineers and is generally used in describing the composition of alloys, while niobium is the accepted name in the scientific community. Since this report is directed toward engineering applications of strategic materials, the name columbium is used here,

[2]At high temperatures and pressure, molecular hydrogen dissociates into atomic hydrogen, penetrates steel (or other metals), and reacts with the carbon in the steel to form methane. This causes the metal to fail. This hydrogen attack is decreased with the addition of carbide stabilizers, such as chromium, molybdenum, tungsten, vanadium, and titanium as we]] as columbium,

Table C-4.—Beryllium: U.S. Imports, World Production, and Reserves

Sources of U.S. imports (1979.82):

Country	Percent
Brazil	38
China	40
South Africa	5
Rwanda	4
Other	13

NOTE: 1982 U.S. net import reliance = W.

World mine production and reserves, 1982 (short tons):

Country	Mine production Amount	Mine production Percent	Reserves
Brazil	35	28	Not adequately delineated
South Africa	3	2	
Rwanda	4	3	
Argentina	1	1	
United States	W	NA	
China	NA	NA	
Other market economy countries	3	2	
Other central economy countries	80	63	
World total[a]	126	100	

[a]Does not include United States and China.
NA—Not applicable
W—Withheld to avoid disclosing company proprietary data
SOURCE U S Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984*.

Table C-5.—U.S. Consumption of Columbium, 1978-82

Year	Apparent consumption (short tons)
1978	3,293
1979	3,560
1980	3,767
1981	4,059
1982	3,300

SOURCE US Department of the Interior Bureau of Mines *Mineral Commodity Summaries 1984*

tions. Some of these substitutes are themselves considered strategic.

Columbium deposits exist in the United States, but none are producing, nor are they likely to in the near future. The United States imports all its columbium, either in the form of concentrates and tin slags or as ferrocolumbium. Brazil dominates U.S. imports and indeed world supplies. Its reserves will last for hundreds of years (see table C-6), The only other major source of U.S. imports is Canada, and its deposits are low-grade. A single overwhelmingly dominant source of supply makes for increased vulnerability even when the source is friendly and well-endowed with reserves.

Natural industrial diamonds are included as second-tier strategic materials because U.S. import dependence on them is 100 percent and because no substitutes are available, Another factor making for uncertain supply is that industrial diamond output depends largely on gemstone production and is not directly related to industrial diamond demand. Diamonds are not included in the first tier for two reasons: with the advent of a huge diamond industry in Australia, the western world's nearly complete reliance on African nations will disappear, and even from the limited area of southern Africa, supply has been quite reliable in the past. Table C-7 shows the trend in industrial diamond consumption in the United States.

The major use of industrial diamond stones is in drilling for minerals. Dies, core bits, cutting tool points, and electrical machinery also use natural diamond stone. Synthesized polycrystalline diamonds are competitive with natural stones in some applications where small stones are suitable, but synthesis of large industrial diamonds is not currently commercial. It is expected that eventually half of the demand for natural stones can be replaced by synthetics.

Although the United States currently mines no industrial diamond stones, there are diamond deposits near the Colorado-Wyoming border. The United States is the world's largest consumer of natural industrial diamond stones. As with several other strategic materials in the first and second tiers, supplies are limited to a rather small group of producers. Currently, the main sources of supply of natural stones are South Africa, Zaire, Belgium-Luxembourg, and Great Britain, as shown in

Table C-6.—Columbium: U.S. Imports, World Production, and Reserves

Sources of U.S. imports (1979.82):

Country	Percent
Brazil	75
Canada	6
Thailand	6
Other	13

NOTE 1982 U S net import reliance = 100 percent

World mine production and reserves, 1982 (short tons):

Country	Mine production		Reserves	
	Amount	Percent	Amount	Percent
Brazil	13,165	83	4,000,000	93
Canada	2,417	15	175,000	4
Nigeria	90	1	100,000	2
Zaire	10	<1	50,000	1
United States	Small	NA	Negligible	NA
Other market economy countries	***98***	1	9,500	0
Other central economy countries	NA	NA	NA	NA
World total	15,780	100	4,334,500	100

[a]Does not include United States or central economy countries

NA—Not applicable

W—Withheld to avoid disclosing company proprietary data

NOTE *American Metal Market* (Mar ?9, 1983) reports that China has 400 million metric tons of columbium-bearing iron ore The Japanese are planning to extract the columbium during steelmaking

SOURCE U S Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984*

Table C-7.—U.S. Consumption of Natural Industrial Diamond Stones, 1978-82

Year	Apparent consumption (million carats)
1978	3.7
1979	4.0
1980	3.4
1981	3.7
1982	2.9

SOURCE: U.S Departmnant of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984.*

table C-8. Australia is beginning full-scale production from its enormous reserves, with production expected to be about 2 million carats in 1983 and 15 million to 20 million carats in 1985, and could easily become the world's largest producer of industrial diamonds. Other countries with substantial, identified deposits are Ghana, Botswana, and the Soviet Union.

Natural graphite sources are well-diversified and its end uses are less critical as those for other materials considered here. Graphite is, however, considered strategic to some degree because of its wide-ranging uses and the many industries that employ it. Moreover, natural graphite comes in several forms, and certain uses require one particular form. Of these specific varieties, some are found in a very few places in the world. Because of its uses in the basic industries, demand for graphite has dropped with the 1982 recession, as shown in table C-9.

Of the many varieties of graphite (with distinctive characteristics and uses) the primary types are flake, lump, and amorphous. Amorphous is the cheapest, at $60 to $80/short ton, flake in the mid-range at $200 to $l,000/short ton, and lump, the most expensive at $800 to $2,00()/short ton. Natural graphite is used mainly to raise the carbon content in steel production. It is also used in refractories, for dressings and molds in foundry operations, and as lubricants. Because of its superior ability to conduct heat, crystalline flake is the only type of graphite used in crucibles.

Substitute and alternative materials do not perform as well as graphite for most applications. For example, in steelmaking, graphite goes into the metal more easily than do other sources of carbon because it does not emit as many volatiles. One significant functional substitution exists, however, Teflon and similar materials are increasingly used for bearings, so that the need for graphite lubricants for steel bearings has declined.

No natural graphite was produced domestically in 1982, although one deposit in Texas has been mined recently, and another in Alabama is being investigated. There are also deposits in Alaska, Idaho, Montana, New York, and Pennsylvania which are not economically viable at present.

Table C-8.—Natural Industrial Diamonds: U.S. Imports, World Production, and Reserves

Sources of U.S. imports (1979-82) (diamond stones):

Country	Percent
South Africa	60
Zaire	14
Belgium-Luxembourg	7
United Kingdom	7
Other	12

NOTE: 1982 US. net import reliance = 100 percent

World mine production and reserves, 1982 [a] (million carats):

Country	Mine production		Reserves	
	Amount	Percent	Amount	Percent
Soviet Union	8.5	***25***	80	8
Zaire	8.6	***25***	150	15
South Africa	5.8	***17***	70	7
Botswana	6.6	***19***	125	13
Ghana	0.6	***2***	15	2
Australia	0.5	1	500	50
China	1.6	4	20	2
Other market economy countries	2.4	7	30	3
World total	34.6	100	990	100

[a] Includes all natural industrial diamonds

SOURCE' U S. Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984*

Table C-9.—U.S. Consumption of Natural Graphite, 1978.82

Year	Apparent consumption (thousand short tons)
1978	W
1979	74
1980	49
1981	55
1982	43

W—Withheld to avoid disclosing company proprietary data

SOURCE: U.S Department of the Interior, Bureau of *Mines, Mineral Commodity Summaries 1984*

U.S. demand for graphite is met by imports of crystalline flake from Madagascar, lump and chip from Sri Lanka, and amorphous from Mexico. Korea, the Soviet Union, and China also export graphite to the United States. In general, reserves of graphite around the world are large and are not isolated in any particular geographic region, but specific types of graphite are highly localized. Table C-10 illustrates the U.S. imports, world production, and reserves.

Sri Lanka, sole world source for lump graphite, attempted to take advantage of the situation by escalating prices in the 1970s. This encouraged end-users to begin designing out requirement for lump graphite. As a result, Sri Lanka's market for its lump graphite is shrinking. It is this potential to substitute one type of graphite for another that puts graphite into the second tier of strategic materials.

Titanium and rutile are considered together here, because rutile is one of the ores from which titanium sponge (metal) is produced. Most rutile is consumed in the production of titanium dioxide pigment (see table C-n for consumption statistics). Titanium has critical uses in certain industries—in particular, aerospace—and thus is strategic to some degree. It is not included in the first tier because the main sources of supply, of both rutile and titanium metal, are political allies of the United States and are considered secure suppliers. Also, substitutes do exist for many uses. Moreover, synthetic rutile can be produced from domestic ilmenite, another titaniferous ore.

U.S. consumption of titanium metal increased in recent years as the commercial and military aircraft fleets were built up, as shown in table C-12.

The major end use (60 percent) of titanium metal is in jet engines, airframes, and space and missile applications, where it is valued for its high strength and light weight. Another 20 percent of titanium consumed in the United States goes into steel and aluminum alloys, where titanium is used to remove oxygen and nitrogen and to toughen the alloys.

Table C-10.—Natural Graphite: U.S. Imports, World Production, and Reserves

Sources of U.S. imports (1979-82):

Country	Percent
Mexico	63
South Korea	4
Madagascar	6
China	8
Brazil	8
Other	12

NOTE: 1982 U.S. net import reliance = W.

World mine production and reserves, 1982[a] (thousand short tons):

Country	Mine production Amount	Mine production Percent	Reserves Amount
South Korea	39	6	Large
India	49	8	Moderate
Mexico	38	6	Large
Austria	27	4	Large
Madagascar	11	2	Large
Sri Lanka	8	1	Moderate to large
United States	W	—	1,100
Other market economy countries	53	9	Moderate
Other central economy countries	383	63	Large
World total	608	100	1 70,000a

[a]This figure is from Bureau of Mines' statistics which aggregate reserves by continent.

W—Withheld to avoid disclosing company proprietary data

SOURCE U S Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984*

Table C-11.— U.S. Consumption of Rutile, 1978-82

Year	Reported consumption (short tons of concentrates)
1978	253,000
1979	314,000
1980	298,000
1981	285,000
1982	239,000

SOURCE US Department of the anterioBureau of Mines, Mineral Commodity Summaries 1984

Another 20 percent is used in the chemical processing industry, power generation, and marine and ordnance applications.

In some uses, high-nickel steel and superalloy can substitute for titanium alloys. For aircraft and space applications, high-strength, low-weight composite materials are being introduced to replace titanium. Also, new aluminum alloys produced by powder metallurgy techniques (discussed in ch. 7) provide alternatives to titanium in aerospace applications.

There is some rutile mining in the United States, but most of the material is imported (see table C-13). The major import source is Australia, with minor amounts coming from Sierra Leone and India. Brazil has by far the largest reserve base in the world, but current production there is limited. Sources of supply are quite diverse, with producers including Italy, South Africa, and Sri Lanka, as well as the other countries mentioned.

Ilmenite, a titaniferous ore which is abundant in this country, can be used to produce synthetic rutile, from which titanium can be made. A new synthetic rutile plant is being planned by a firm which mines ilmenite in Florida. The process to be used is the same as the one in current use in Australia. For most domestic producers of metal (mainly located on the west coast) it is cheaper to import rutile from Australia than to use synthetic rutile derived from domestic ilmenite. According to an industry source, the costs of starting up more synthetic rutile plants and shipping the produce to domestic sponge producers are the only barriers to U.S. self-sufficiency in titanium raw materials.

Major U.S. import sources for titanium sponge metal have been Japan, China, the Soviet Union, and Great Britain (see table C-14). The United States has enough processing capacity to produce all the titanium metal required for domestic consumption, but about 35 percent of capacity was idle in 1982,

Tantalum performs essential functions in certain products, and some of those products themselves meet critical needs, Others are nonessential. The present major U.S. import sources for tantalum are judged not to be highly reliable, which adds an element of risk. Yet worldwide ore production is quite substantial and diverse. For these combined rea-

Table C-12.—Rutile: U.S. Imports, World Production, and Reserves

Sources of U.S. imports (1979.82):

Country	Percent
Australia	69
South Africa	9
Sierra Leone	14
Other	8

NOTE 1982 U.S. net import reliance = W

World mine production and reserves, 1982 (thousand short tons of concentrates):

Country	Mine production		Reserves	
	Amount	Percent	Amount	Percent
Australia	243	64	10,000	7
South Africa	52	14	7,000	5
Sierra Leone	53	14	4,000	3
Sri Lanka	14	4	6,000	4
India	9	2	4,000	3
United States	W	NA	3,000	2
Brazil	—	0	100,000	70
Italy	—	0	6,000	4
Central economy countries	10	3	3,000	2
World total	381[a]	100	143,000	100

[a]Excludes U S production
NA—Not applicable
W—Withheld to avoid disclosing company proprietary data

SOURCE U S Department of the Interior, Bureau of Mines, &f ineral Commodity Summaries 7984

Table C-13.—U.S. Consumption of Titanium Sponge, 1978.82

Year	Reported consumption (short tons)
1978	19,854
1979	23,937
1980	26,943
1981	31,599
1982	17,328

SOURCE U S Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984*

sons, tantalum is in the second tier of strategic materials.

As indicated in table C-15, annual U.S. consumption of tantalum is small, on the order of 1 million pounds per year.

The largest share of U.S. tantalum consumption (54 percent) goes into electronic capacitors. Capacitors are used in all areas of electronics: computers and office equipment, telecommunications, instruments and controls, consumer, and automotive. Some areas of capacitor use maybe considered essential and others not. For example, in the United States, consumer electronics accounts for about 12 percent of tantalum capacitors. (In Japan, by contrast, two-thirds of tantalum capacitors are used for this purpose.) Moreover, where size and stability are not essential features (as in consumer products), aluminum electrolytic capacitors are competitive and can substitute for tantalum capacitors. Thus, only a limited proportion of tantalum use in capacitors may be regarded as critical.

Another important use of tantalum (27 percent) is in cemented carbide metalworking tool bits. As an additive, tantalum carbide improves hot hardness and crater resistance in tool bits. Columbium carbide is a suitable substitute for the purpose. About 9 percent of tantalum consumption goes into high-temperature superalloys for critical parts (blades and vanes of gas-turbine engines for aircraft). The other principal use of tantalum is in mill products, mainly used by the chemical industry for such items as corrosion-resistant heat exchangers and tank linings. Substitute products are glass-lined containers, graphite, Hastelloy C, titanium, and zirconium.

The United States imports 90 percent of its tantalum in the form of concentrate and tin slags. The largest supplier is Thailand, with smaller amounts coming from Canada, Malaysia, and Brazil. Malaysia and Thailand ship substantial amounts of tantalum-containing tin slags, a source that is likely to decline as the old tin slags become depleted, Canada is the largest source of natural tantalum minerals, but Australia may eventually supply a larger portion. In addition, there are reserves of tantalum in Nigeria and Zaire. Nigeria's tantalum is a byproduct of columbium production; demand for Nigerian columbium may decline as production of columbium oxide in Brazil gears up. Nigerian tantalum production may then drop accordingly. Table C-16 contains statistics relating to tantalum,

No significant mining of tantalum has occurred in the United States since 1959. This country has 3.4 million pounds of tantalum resources in identified deposits, but they are uneconomic to develop at current prices. For several years world tantalum prices have been falling, which probably indicates confidence about future raw materials supply. As

Table C-14.—Titanium Sponge: U.S. Imports, World Production, and Reserves

Sources of U.S. imports (1979-82):

Country	Percent
Japan	85
China	11
Soviet Union	4

NOTE" 1982 U S net import reliance = W

World mine production and reserves, 1982 (short tons):

Country	Mine production		Reserves	
	Amount	Percent	Amount	Percent
Soviet Union	44,000	53	50,000	39
United States	15,600	19	33,500	26
Japan	18,600	23	36,000	28
United Kingdom	2,600	3	5,500	4
China	1,500	2	3,000	2
World total	82,300	100	128,000	100

w—Withheld to avoid disclosing company proprietary data

SOURCE U S Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 7984*

Table C-15.–U.S. Consumption of Tantalum, 1978.82

Year	Apparent consumption (short tons)
1978	560
1979	720
1980	590
1981	630
1982	530

SOURCE: U.S. Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984*.

mentioned below, production capacities of developing nations for both tin and tantalum have been rising.

Tin is included in the second tier mainly because it occurs geologically with tantalum. Because of this geological pairing, tin supplies share characteristics of vulnerability with tantalum.

Tin consumption in the United States is shown in table C-17. Tin is used in cans and containers, electrical applications (solder), and in construction and transportation. Substitutions for most of these uses are widely available. There are a multitude of alternative materials for tin cans and containers. Epoxy resins can be used in place of solder in some nonelectrical uses, and aluminum or copper base alloys or plastics can be used in place of bronze. Lead-base bearing alloys and plastics can be used for tin-containing bearing metals as well. Thus, the essential use of tin is limited to electric solder. Nonetheless, because the material is pervasive in many industries, a serious interruption of supply might cause severe economic dislocation, until substitutes could be adopted.

The United States relies on imports for 72 percent of its tin requirements. Major import sources at present are Malaysia, Thailand, Bolivia, and Indonesia. Quite a few other countries have large deposits (China, Soviet Union, Burma, Brazil, Australia, Nigeria, the United Kingdom, and Zaire), as shown in table C-18. In the developed world, a British mining consortium is going ahead with the first commercial use of a suction dredge for the seabed mining of tin in sands off the coast of Cornwall.

Small quantities of tin are produced domestically, as a byproduct of molybdenum mining in Colorado, and from placer deposits in Alaska and New Mexico. Over 20 percent of the tin consumed in this country comes from recycled scrap.

There is a large inventory of tin in the U.S. stockpile, which essentially serves as another supply source, since sales are made constantly to reduce the surplus, From July 1980, when tin sales began, to the end of 1982, over 10,467 tonnes of tin were disposed of from the stockpile. This amounted to approximately 7 percent of U.S. apparent consumption over that period.

Vanadium is on the second-tier list because of its critical uses. It is employed in a variety of steel and

Table C-16.—Tantalum: U.S. Imports, World Production, and Reserves

Sources of U.S. Imports (1979-82):

Country	Percent
Thailand	42
Canada	11
Malaysia	9
Brazil	8
Other	30

NOTE: 1982 U.S. net import reliance = 92 percent.

World mine production and reserves, 1982 (short tons):

Country	Mine production		Reserves	
	Amount	Percent	Amount	Percent
Brazil	115	31	1,500	4
Canada	85	23	3,000	9
Australia	85	23	7,500	22
Thailand	10	3	10,000	29
Nigeria	12	3	5,000	15
Zaire	10	3	3,000	9
Malaysia	—	o	2,000	6
Mozambique	NA	NA	NA	NA
Other market economy countries	50	14	2,000	6
Other central economy countries	NA	NA	NA	NA
World total	367	100	34,000	100

NA—Not applicable.

SOURCE: U.S. Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984*.

Table C-17.—U.S. Consumption of Tin, 1978-82

Year	Apparent consumption (short tons)
1978	70,304
1979	76,262
1980	60,068
1981	60,012
1982	44,364

SOURCE" US Department of the anterior, Bureau of *Mines, Mineral Commodity Summaries 1984*

alloy products and as a chemical catalyst. Of the possible substitutes for vanadium, many are themselves more strategic. U.S. vanadium supplies and processing capacity are sufficient to meet this country's requirements. Yet a considerable amount is being imported at present, which adds an element of vulnerability. Altogether, vanadium probably belongs near the bottom of the list of second-tier strategic materials.

Vanadium is another material that is used in comparatively small quantities, as shown in table C-19. About 80 percent of the U.S. vanadium consumption is used as a microalloying agent in steelmaking. Vanadium imparts hardening properties to steel by means of grain refinement. It is used in high-speed tool steels and high-temperature rotors because it forms stable carbides and resists high-temperature abrasion. It is used in crankshafts, pinions, and gears because of its shock and wear resistance, The high strength-to-weight ratios of steels containing vanadium (HSLA and full-alloy steels) make these steels valuable in weight-saving components. Because of its various uses in steel products, demand for vanadium is tied to the demand for steel.

Ten percent of U.S. vanadium demand is in titanium alloys, where it provides strength and workability. The rest of U.S. vanadium consumption is in the chemical industry, where vanadium is used as a catalyst, mainly in the production of sulfuric acid.

Many metals are interchangeable with vanadium to some degree in alloying; examples are columbium, molybdenum, manganese, titanium, and tungsten. Platinum can be used in place of vanadium as a catalyst in the chemical industry.

Table C-18.—Tin: U.S. Imports, World Production, and Reserves

Sources of U.S. imports (1978-81):

Country	Percent
Malaysia	39
Thailand	21
Bolivia	17
Indonesia	13
Other	10

NOTE: 1982 U.S net import reliance = 72 percent.

World mine production and reserves, 1982 (short tons):

Country	Mine production		Reserves	
	Amount	Percent	Amount	Percent
Malaysia	57,600	22	1,320,000	12
Soviet Union	40,800	15	1,100,000	10
Indonesia	40,200	15	1,705,000	16
Thailand	28,700	11	1,320,000	12
Bolivia	29,500	11	1,080,000	10
China	16,500	6	1,650,000	15
Australia	14,000	5	385,000	4
Brazil	10,500	4	440,000	4
Great Britain	4,400	2	286,000	3
Zaire	2,400	1	220,000	2
Nigeria	3,000	1	308,000	3
Burma	1,900	1	550,000	5
United States	Negligible	—	77,000	1
Other market economy countries	12,100	5	231,000	2
Other central economy countries	4,000	2	66,000	1
World total	265.600[a]	100	10.738,000	100

[a]Excludes U.S. production

SOURCE: U S Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984*

Table C-19.—U.S. Consumption of Vanadium, 1978-82

Year	Apparent consumption (short tons)
1978	8,164
1979	10,168
1980	8,521
1981	9,584
1982	6,406

SOURCE. U S. Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984.*

Overall, U.S. net import reliance for vanadium (24 percent) is not as high as for most other strategic materials, but this is due in part to the depressed state of the steel industry in 1982. The foreign sources of supply are not very diverse; the majority of vanadium imports originate in South Africa, as table C-20 indicates. The major world deposits are located in South Africa, the Soviet Union, the United States, and China. These same countries are the world's leading producers of vanadium. In this country, vanadium is usually mined as a coproduct or byproduct of uranium or phosphorus; an exception is the vanadium mine in Hot Springs, Arkansas. Because of this geological pairing, continued U.S. production may be somewhat uncertain, since it depends to a considerable degree on the market for unrelated minerals. Although the United States has the reserves to be self-sufficient, market forces may at times favor imports.

Vanadium can also be recovered from iron slags and petroleum residues. Japan and the United States are the only countries currently producing vanadium from petroleum. The United States uses Venezuelan crude oil as a vanadium resource.

Vanadium is also imported in semiprocessed form as ferrovanadium, largely from industrialized countries. Canada, Belgium, Luxembourg, and West Germany supply approximately 90 percent of U.S. ferrovanadium imports. Canada processes U.S. and South African ores into ferrovanadium and then exports it to this country.

Table C-20.—Vanadium: U.S. Imports, World Production, and Reserves

Sources of U.S. imports (1979.82):

Country	Percent
South Africa	54
Canada	10
Finland	7
Other	29

NOTE: 1982 U.S. net import reliance = 24 percent.

World mine production and reserves, 1982 (short tons):

Country	Mine production Amount	Mine production Percent	Reserves Amount	Reserves Percent
South Africa	13,200	36	8,600,000	47
Soviet Union	10,500	29	4,500,000	25
China	5,000	14	1,800,000	10
United States	4,100	11	2,400,000	13
Finland	3,470	10	100,000	1
Australia	110	<1	270,000	1
Other market economy countries	120	<1	600,000	3
World total	36,500	100	18,250,000	100

SOURCE' U.S. Department of the Interior, Bureau of Mines, *Mineral Commodity Summaries 1984*

This appendix draws on information contained in the U.S. Bureau of Mines publications *Mineral Commodity Summaries 1983, Mineral Facts and Problems 1980,* and issues of *Mineral Commodity Profiles 1983* for the specified metals.