4. PRODUCTION, IMPORT, USE, AND DISPOSAL

4.1 PRODUCTION

Vanadium is widely, but sparsely, distributed in the earth's crust (Byerrum et al. 1974; Windholz 1983). It may be found at levels as great as 0.07% in the lithosphere and exists in the form of over 50 different mineral' ores (Grayson 1983). The principal ores are carnotite, patronite, roscoelite, and vanadinite (Grayson 1983; Byerrum et al. 1974; Weast 1969; Windholz 1983). Vanadium is also found in phosphate rock, some iron ores, and crude petroleum deposits. Flue-gas deposits from oil-fired furnaces have been found to contain up to 50% vanadium pentoxide (Brooks 1986; Grayson 1983; Symanski 1983; Weast 1969).

Vanadium occurs primarily as a by-product or coproduct during the extraction of other compounds such as iron, titanium, phosphate, or petroleum. Within the United States it is extracted from carnotite, phosphate-rock deposits, titaniferous magnetites, and vanadiferous clays. A process called salt roasting during the initial stage of extraction produces the oxide concentrate. The ores, petroleum residues, iodide thermal decomposition products, and slags formed during ferrovanadate production are crushed, dried, finely ground, mixed with a sodium salt, and roasted. The product, sodium metavanadate, is then mixed with sulfuric acid, and the resultant precipitate dried to form vanadium pentoxide (Brooks 1986; Browning 1969; Byerrum et al. 1974; Grayson 1983). The vanadium pentoxide can then be processed further to form the required vanadium compound. Pure vanadium is difficult to obtain as it tends to be readily contaminated by other elements. Methods to extract pure vanadium include calcium reduction, solvent extraction, thermal decomposition, and electrolytic refining (Grayson 1983; Weast 1969).

World production of vanadium from ores, petroleum concentrates, and slags has remained fairly constant over the last few years and is presently around 34,300 tons (Hilliard 1987). The levels of vanadium recovered from petroleum residues, ashes, and spent catalysts throughout the world are not available; however, within the United States and Japan, recovery of vanadium and its compounds, in particular vanadium pentoxide and ferrovanadium, increased between 1983 and 1987.

Unfortunately, precise data on domestic production of vanadium from ores, concentrates, and slags from 1985 to the present are unavailable in order to avoid disclosing company proprietary data. However, the amount of vanadium recovered from ores and concentrates decreased from 2,171 tons in 1983 to 1,617 tons in 1984, and production levels from these sources are reported to have continued to decline between 1985 and 1987. This decline was partially compensated for by increased production from low-cost petroleum residues, utility ash, and spent catalysis. Production volumes from these sources increased from 893 tons in 1983 to 2,695 tons in 1985, an increase of approximately 281%; volumes remained reasonably constant through 1987 (Hilliard 1987).

TABLE 4-1. Facilities that Manufacture or Process Vanadium and Compounds[a]

Facility	Location	Maximum Amount on site (lbs)	Use
Harvey Engineering & Manufacturing Company	Hot Springs, AK	1,000-9,999	For sale/distribution; as an article component
Vulcraft Division Of Nucor Corp.	Fort Payne, AL	10,000-99,999	As an article component
Nibco, Inc. Blytheville Division	Blytheville, AR	1,000-9,999	As an article component
Aerochem, Inc.	Orange, CA	100-999	As an impurity; as a formulation component
Union Pacific Resources Company	Wilmington, CA	1,000-9,999	As a processing aid
Kloppenberg & Company	Englewood, CO	1,000-9,999	In ancillary or other uses
Laclede Steel Company .	Alton, IL	10,000-99,999	Import; as a byproduct; as a reactant; as a formulation component; as an article component
Caterpillar Inc. Seal Ring	Peoria, IL	10,000-99,999	As an article component; in ancillary or other uses
Ltv Steel Company Inc.	East Chicago, IN	1,000-9,999	As a formulation component
New York Blower Company	La Porte, IN	10,000-99,999	In re-packaging
Syndicate Store Fixtures, Inc.	Middlebury, IN	10,000-99,999	As an article component
Dana Corporation	Syracuse, IN	10,000-99,999	As a formulation component
Total Petroleum, Inc.	Arkansas City, KS	100,000-999,999	As a processing aid
Koch Sulfur Products Company	Desoto, KS	10,000-99,999	As a processing aid
National-Southwire Aluminum	Hawesville, KY	1,000-9,999	As a reactant
Browning Manufacturing Division	Maysville, KY	100,000-999,999	Import; for sale/distribution
Baltimore Specialty Steels Corporation	Baltimore, MD	10,000-99,999	Produce; as a byproduct; as a formulation component
Koch Refining Company	Saint Paul, MN	10,000-99,999	As an impurity
Koch Sulfur Products Company	Wilmington, NC	100,000-999,999	As a processing aid
Shieldalloy Metallurgical Corporation	Newfield, NJ	1,000,000-9,999,999	Produce; import; for sale/distribution; as an impurity; as a formulation component; in re-packaging
Shieldalloy Metallurgical Corporation	Cambridge, OH	1,000,000-9,999,999	For on-site use/processing; as a byproduct; as a reactant
Canton Drop Forge	Canton, OH	No Data	As an article component
Buckeye Steel Castings	Columbus, OH	1,000-9,999	As an article component
Sohio Oil Company Toledo Refinery	Oregon, OH	1,000-9,999	As an impurity; as a processing aid
Titanium Business Operation	Milwaukie, OR	1,000-9,999	As an article component
Oregon Steel Mills, Inc.	Portland, OR	1,000-9,999	As a reactant
Blaw Knox Corporation Blaw Knox Equipment Division	Blawnox, PA	100,000-999,999	As an article component
Lukens Steel Company	Coatesville, PA	10,000-99,999	As an article component
Ajusta Buckets, Inc.	Erie, PA	1,000-9,999	For on-site use/processing; as an article component; as a manufacturing aid

TABLE 4-1 (Continued)

Facility	Location	Maximum Amount on site (lbs)	Use
Sharon Steel Corporation	Farrell, PA	1,000-9,999	Import; as a byproduct; as a formulation component; as an article component
BP Oil Company - Marcus Hook Refinery	Marcus Hook, PA	1,000-9,999	As a processing aid
Lockheed Aeromod Center, Inc.	Greenville, SC	0-99	As an article component
Phillips 66 Company Sweeny Refinery and Petrochemical	Sweeny, TX	100,000-999,999	As a processing aid
Du Pont Victoria Site	Victoria, TX	10,000-99,999	As a processing aid
Roanoke Electric Steel Corporation	Roanoke, VA	1,000-9,999	As a formulation component
Harnischfeger Corporation	Milwaukee, WI	1,000-9,999	Produce; as a byproduct
Blaw Knox Rolls	Wheeling, WV	10,000-99,999	As a formulation component

[a]Derived from TRI87 (1989)

The major facilities within the United States that manufacture or process vanadium and vanadium-containing compounds are listed in Table 4-1.

4.2 IMPORT/EXPORT

The import of vanadium by the United States can be split into three different products: vanadium-containing materials such as ores, slags, and residues from which the vanadium must still be recovered; ferrovanadium; and manufactured vanadium compounds (principally vanadium pentoxide). Due to shortages of domestic ore and petroleum residues, imports of the former increased substantially from 1983 to 1987, rising from 58 to 2,264 tons. On the other hand, imports of ferrovanadium have declined from 1,461 tons in 1984 to 422 tons in 1987. Imports of vanadium pentoxide were approximately 400 tons in both 1984 and 1987, despite falling to as low as 63 tons in 1985. In 1986, the top four exporters of vanadium to the United States were Austria, Canada, the Federal Republic of Germany, and the Republic of South Africa (Hilliard 1987).

Despite being a net importer of raw vanadium materials, the United States has remained an exporter of processed vanadium products. The United States exports vanadium principally in the form of vanadium pentoxide, which is the primary source for the production of chemicals, catalysts, alloys, and other vanadium compounds. Vanadium pentoxide and catalysts containing vanadium pentoxide have accounted for between 61% (1987) and 82% (1984) of all domestic exports. In 1984, the United States exported a total of 4,498 tons of vanadium. Since then, exports have declined, reaching a level of 2,486 tons in 1986 and remaining fairly constant through 1987. The major importers of vanadium from the United States are Canada, the Federal Republic of Germany, Japan, and Mexico. These are followed by Taiwan and the Republic of Korea (Hilliard 1987).

4.3 USE

Vanadium and its compounds are currently used for a wide variety of purposes. The annual consumption of vanadium within the United States increased from 3,277 tons in 1983 to 4,883 tons by 1985 and remained around this level through 1987. Approximately 83% of the vanadium consumed in the United States is utilized as an alloying agent in the steel industry (Hilliard 1987). These steels are used in a variety of products, such as automobile parts, springs, and ball bearings. Fourteen percent of domestic vanadium consumption is used in the production of ferrovanadium alloys. These are invaluable in the manufacture of jet aircraft engines. Likewise, the nonferrous titanium alloys are essential in the manufacture of supersonic aircrafts. Despite accounting for around 0.3% of domestic consumption, vanadium compounds also have an important role as industrial catalysts. Vanadium-containing catalysts are used in several oxidation reactions such as the manufacture of phthalic anhydride and sulfuric acid, as well as in the

production of pesticides and black dyes, inks, and pigments, that are used by the textile, printing, and ceramics industries. Other minor functions of vanadium compounds include their use as color modifiers in mercury-vapor lamps, driers in paints and varnishes, corrosion inhibitors in flue-gas scrubbers, and as components in photographic developers.

In the past, vanadium compounds were also used in refractories as a green colorant for glass and as a depolarizer in ultraviolet screening glass. Future applications of vanadium compounds may include an increased number of uses as a catalyst, a potential role in superconductors, thermal or lightactivated resistor-conductors, vanadate glasses, electro-optical switches, and the production of high magnetic fields (Brooks 1986; Browning 1969; Grayson 1983; Hilliard 1987; Mackinson et al. 1978; Symanski 1983; Weast 1969).

4.4 DISPOSAL

Where possible, vanadium compounds are recycled rather than disposed. Vanadium-containing products, such as vanadium pentoxide dust, that are spilled or are not being recycled may be disposed following treatment under current federal and state regulations. In the case of released vanadium pentoxide fumes, cleanup of the area through ventilation is recommended. For vanadium spills, ventilation and absorption of the liquid by sand or another similarly noncombustible absorbent material is required. The contaminated absorbent material should then be removed to a safe place away from potential human exposure before being placed in a secured sanitary landfill. Consultation with a hazardous material disposal expert is also suggested (Dutch Safety Institute 1980; Grayson 1983; Hilliard 1987; HSDB 1990).