# ATI Commercial Vanadium

## Vanadium

### INTRODUCTION

Vanadium is widely dispersed in the earth's crust occurring in many types of deposits. Most vanadium is currently obtained as a by-product or co-product from titanomagnetites, petroleum, uranium ores, and phosphate rock. Table 1 shows the abundance of vanadium in the earth's crust relative to some familiar elements.

Commercial production of vanadium was begun in the 1960s when it was required for evaluation as a structural material for breeder reactors. ATI and several other companies produced small quantities for this purpose. In 1979, ATI again began to produce vanadium in 400-700 lb. ingots. Recent demand has justified scale-up to produce 16" diameter ingots weighing up to 4500 lbs. This increased demand for vanadium has been due, in part, to its many attractive properties. These unique properties include:

- Relatively low density (6.1 gms/cc)
- Low neutron capture cross section
- Relatively high strength at elevated temperature
- Good fabricability
- Low rate of neutron embrittlement
- Relative abundance
- Corrosion resistance
- Superconductivity
- Low-temperature ductility.

**TABLE 1 - RELATIVE ABUNDANCE OF VANADIUM IN THE EARTH'S CRUST***

| | Al | Fe | Mg | Ti | Mn | Zr | Cr |
|---|---|---|---|---|---|---|---|
| ppm | 81,300 | 50,000 | 20,800 | 4,400 | 1,000 | 220 | 200 |
| | **V** | **Zn** | **Ni** | **Cu** | **W** | **Nb** | **Mo** |
| ppm | 150 | 130 | 80 | 70 | 69 | 24 | 15 |

*From CF'C Handbook, 61st Edition, Weast.

### ALUMINOTHERMIC REDUCTION

ATI produces vanadium through aluminothermic reduction of high purity vanadium pentoxide as follows:

$1OAI+3V_2\,0_5$ -------> $6V+5Al_2\,0_3$

Excess aluminum is added to lower the oxygen content of the reduced metal and to increase the yield of vanadium The excess aluminum also assists in the removal of oxygen during the subsequent electron beam melting.



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## ELECTRON BEAM MELTING

Electron beam melting is an accepted method for purifying refractory metals such as tantalum, niobium, and vanadium. The high melting points and comparatively low vapor pressures allow purification by vaporization of impurities with higher vapor pressures. Vanadium does not purify as readily as tantalum or niobium because of its lower melting point and higher vapor pressure; however, purities of up to 99.9% can be achieved by melting the ingot several times.

## TYPICAL CHEMISTRY

Typical chemistry for current production commercial vanadium is given in Table 2.

| TABLE 2 - TYPICAL CHEMISTRY FOR COMMERCIAL VANADIUM | | | | | | | |
|---|---|---|---|---|---|---|---|
| | O | N | H | C | P | S | Si |
| ppm | 350 | 180 | <5 | 60 | <30 | <20 | 400 |
| | Fe | Al | Cr | Mo | Nb | Ni | |
| ppm | <400 | 300 | <20 | 80 | 60 | <20 | |

Figures calculated by weight • Hardness BHN Average 60 (500Kg load)

## MILL PRODUCTS

Vanadium, a soft and very ductile metal, is available in plate, sheet, foil, billet, bar, rod and wire. Tubing is available by special order.

## PHYSICAL PROPERTIES

| | |
|---|---|
| Atomic Number | 23 |
| Atomic Weight | 50.942 |
| Density (g/cc at 200ºC)<br>(lbs./in$^3$) | 6.1<br>0.221 |
| Crystal Structure | body centered cubic |
| Laftice Parameters, Calcium reduced<br>(Iodide) | 3.0278<br>3.0258 |
| Recrystallization Temperature ºC | 800º to 1010ºC |
| Melting Point | 1900ºC |
| Boiling Point | 3400ºC |
| Coefficient of Linear Thermal Expansion per ºC, 23º to 100ºC | 8.3 x $10^{-6}$ |
| Thermal Conductivity (cal/ºC/cm$^2$ /cm/sec) (100ºC) | 0.074 |
| Electrical Resistivity (microhm-cm at 20ºC) | 24.8 to 26.0 |
| Specific Heat (cal/g/ºC 32º to 100ºC) | 0.119 |
| Superconductivity (Tc) | -268.7ºC H. R. E. |
| Magnetic Susceptibility (Paramagnetic) | +1.4 x $10^{6}$ |
| Electronic Work Function | 3.79 e. V. |



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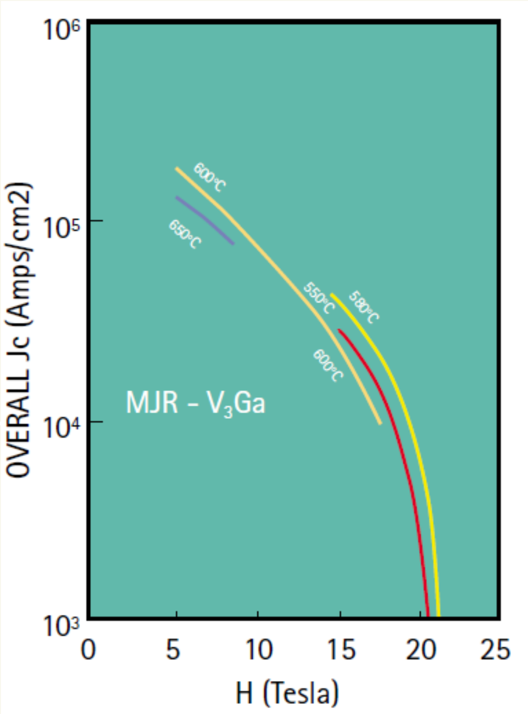
**Figure 1:** Critical current density (noncopper) vs. magnetic field for V3Ga wire at various reaction temperatures.




## MECHANICAL PROPERTIES (TYPICAL)

| | |
|---|---|
| Modulus of Elasticity in Ten, psi | 20 x $10^6$ |
| Tensile Strength, annealed sheet, (psi) | 29-35,000 |
| Yield Strength, annealed sheet, 0.2% offset (psi) | 18-25,000 |
| Elongation, annealed sheet, % in 2 inches | 35-60 |
| Young's Modulus, annealed sheet, (psi) | 18 to 20 x $10^6$ |
| Hardness, Brinell, electron beam ingot | 60 |
| Poisson's Ratio | 0.36 |

## NUCLEAR PROPERTIES

Thermal Neutron Absorption Cross Section, Barns 4.7 ± .02

## REACTOR APPLICATION

Vanadium has a low fusion-neutron cross section, and its inelastic-scattering cross section is also quite small. These favorable nuclear properties, coupled with vanadium's high melting point, ductility, and good physical properties, make the metal of particular interest as a structural material for fast reactors. Favorable alloying characteristics with uranium also make the metal of interest as a diluent, although the transport cross section is small. The thermal neutron cross section of vanadium is large, however, and its usefulness in thermal reactors is limited.



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## CORROSION RESISTANCE

At room temperature, vanadium and its alloys have excellent resistance to corrosion in salt water and dilute hydrochloric acid; good corrosion resistance in sodium hydroxide solutions; poor corrosion resistance in nitric acid solutions. Resistance to attack by liquid-lithium metal is excellent. With liquid-sodium metal resistance is excellent, if oxygen is rigorously excluded.

## CORROSION LABORATORY SERVICES

ATI's Corrosion Laboratory offers the following services:

- Materials selection and evaluation of customers' test results and specimen.
- Corrosion testing according to the methods established by ASTM, NACE, EPA, as well as other groups and agencies.
- Corrosion testing according to the methods established by ATI customers.
- Material failure analysis.

| TABLE 3 - TYPICAL PROPERTIES OF PURE VANADIUM PRODUCED AT WAH CHANG (ASTM-E8) | | | | |
|---|---|---|---|---|
| **Sample** | **Reduction In Area** | **Elongation** | **Tensile Strength** | **Yield Strength** |
| 0.125" wire | 96 | 42 | 31,700 | 18,400 |
| 0.250" wire | 95 | 60 | 31,300 | 25,700 |
| 0.010" foil | Longitudinal | 2<br>2 | 69,500<br>69,900 | 63,900<br>64,100 |
| 92% cold work<br>No anneal | Transverse | 2<br>2 | 80,300<br>79,900 | 70,600<br>70,200 |

## MACHINING

High speed steel and carbide tools may be used to machine vanadium. Speed as well as tool angles and lubrication should be monitored to avoid galling.

## TURNING

See general instructions for turning vanadium given in Table 4. These instructions are recommended as a starting point for working with vanadium. Adjustments to these procedures should be made to accommodate the different compositions of each vanadium alloy.

| TABLE 4 - TOOLING RECOMMENDATIONS FOR MACHINING VANADIUM | |
|---|---|
| **Approach Angle** | 15º to 20º |
| **Side Rake** | 30º to 35º |
| **Side and End Clearance** | 5º |
| **Plan Relief Angle** | 15º to 20º |
| **Nose Radius** | 0.020" to 0.030" |
| **Cutting Speed** | 60 to 80 ft./min. with HSS<br>250 to 300 ft./min. with carbide |
| **Feed, Roughing** | 0.008" to 0.012"/revolution |
| **Feed, Finishing** | 0.005" maximum/revolution |
| **Depth of Cut** | 0.030"to 0.125" |



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