THE VIABILITY OF BENEFICIATING VANADIUM PENTOXIDE TO FERROVANADIUM IN SOUTH AFRICA

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A research report submitted to the Faculty of Mining Engineering. University of Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering

Johannesburg, 1992

ABSTRACT

Historically South Africa has enjoyed a privileged position with its vast natural resource base in that it has not needed to generate wealth but has merely explored this base. The only true way to create wealth, is to add value to a commodity by means of beneficiation. South Africa is the world's largest producer of vanadium accounting for approximately 70% of the western world's requirements. Unfortunately the South African producers of vanadium mainly export vanadium in the form of slag and pentoxide, instead of ferrovanadium and other prime alloys.

The principle objective of this research project is to establish whether it would be economically viable for an independent (ie non-integrated) firm to engage in the further downstream processing of vanadium pentoxide. The key success factors determining the competitive feasibility of this project have been identified by analysing the main production factors. The procurement of a vanadium pentoxide supply contract at favourable prices is the most important factor determining the feasibility of this project. The domestic processor will have a competitive edge over competitors abroad as a result of transport cost savings and stronger marketing links with pentoxide suppliers. Overseas converters, however, who use vanadium slag as a starting feedstock will still maintain a comparative advantage . In addition to vanadium pentoxide costs, the costs of aluminium scrap play a major role in the feasibility of this project. Unfortunately aluminium scrap is substantially cheaper in the Europe and the U.S.A., however, the domestic producer has the option of importing this scrap. In the other major cost areas the producer is competitive. The major ferrovanadium markets are duty protected and thus acts as a further constraint.

A base case scenario, together with several sensitivity analyses have been evaluated which indicate that the project is viable and yields an acceptable rate of return. The project is highly risky and it is proposed that a substantial part of this risk may be reduced if the project is conducted by a vertically integrated firms.

DECLARATION

I declare that this research report is my own, unaided work, except to the extent indicated in the acknowledgements. It is being submitted in partial fulfilment of the requirements for the degree of Master of Science in Engineering in the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.

L.B. CORBETT

.... day of ..20/6.............., 1992

ACKNOWLEDGEMENTS

In compiling this report, use was made of the opinions of a number of industry specialists to whom I am grateful. In particular, I would like to thank Mr Alex Jamieson for his assistance.

Special thanks are due to Dr Anton von Below for his comments on this research report in its preliminary stages.

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LIST OF ABBREVIATIONS

AMV	Ammonium metavanadate
ANC	African National Congress
EEC	European Economic Community
FOB	Free-on-board
GEIS	General Export Incentive Scheme
GFE	Gesellsehaft per Elektrometallugic mGH
GNP	Gross National Product
HSLA	High Strength Low Alloy
HSVC	Highveld Steel and Vanadium
IISI	International Iron and Steel Institute
ISCOR	Iron and Steel Corporation
LME	London Metal Exchange
ME	Market Economies
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing Power Parity
SACOB	South African Chamber of Business
Stratcor	Strategic Minerals Corporation
USA	United States of America
UK	United Kingdom
USSR	Union Soviet Socialist Republic
Vantech	Vanadium Technology
VAT	Value Added Tax

As	arsenic
Al	aluminium
C	carbon
Cr	chromium
Cu	copper
Fe	iron
FeV	ferrovanadium
Mg	magnesium
Ni	nickel
O	oxygen
P	phosphate
Si	silicon
S	sulphur
Ti	titanium
V	vanadium
V_2O_5	vanadium pentoxide
d.c.	direct current
m.w.	megawatt
p.a.	per annum
p.p.m	parts per million

CHAPTER 1
INTRODUCTION

It is often cited by economists that long lasting industrial growth in South Africa can be best stimulated through resource-based industrialisation. Resource-based industrialisation entails primary export processing and basic goods production, based on the domestic processing of natural resources.

In the period 1965 to 1989, the average rate of increase in GNP per capita was just over 0,5% per annum, in contrast to an average of between 2,5% and 3% per annum in the developed or newly developed countries (SACOB, 1991:14). A 6% increase GNP per capita was experienced in Singapore, Korea and Hong Kong. It is believed that the combination of sanctions, disinvestment, political problems and an inward-looking policy have all contributed to South Africa's dismal economic growth performance.

It is proposed that if South Africa wishes to prosper and survive in this increasingly competitive global trade climate, as well as provide jobs for its fast-growing, urbanising black population, an added focus on manufactured exports is of utmost importance. South Africa needs to change its industrial base from one that is based on import replacement and self sufficiency, to one that is export orientated, capable of producing value added products that can compete in world markets in terms of both quality and cost. Clearly the concept of beneficiation features prominently in South Africa's new industrialisation policy.

Beneficiation is defined as the further processing of a mineral beyond the stage of which it first becomes a marketable product (Von Below, 1991:4). Four stages of beneficiation after the production of the saleable raw material have been identified (Robinson and Von Below, 1990:92). They are as follows:

1. Saleable smelted or refined products
2. Fabrication alloys and metals
3. Semi-manufactured goods
4. Fabricated goods

It must be noted that no classification system is precisely applicable to all commodities.

Beneficiation of minerals results in several obvious advantages. Firstly, value added generated by further processing contributes to the country's export earnings and to government revenues. For example, it is estimated that the value added from manufacturing platinum catalytic converters is in the order of 100% - 180% (Financial Mail, 13 July 1990:42).

Secondly, foreign capital is often easier to obtain for such projects than other kinds of investment funds. Thirdly, downstream processing of minerals may contribute to backward and forward linkages in other sectors of the economy. Through this mechanism of production linkages mineral beneficiation, facilitates rapid economic growth. Lastly, if stage 4 beneficiation activities are undertaken the employment generation effects may be substantial. Unfortunately only stage 4 activities are labour intensive, the other three stages being very low in employment generation.

Although often advocated as if its appropriateness is unquestionable, mineral beneficiation projects must like all other other projects be subject to cost-benefit analysis.

The classification system for the beneficiation of mineral commodities has to be modified when examining the subsequent stages of beneficiation of vanadium. Vanadium slag represents the basic saleable raw material. The slag is coproduced from steelmaking operations. Vanadium pentoxide, produced by the roast leach process, in turn represents a stage 1 beneficiated product. The subsequent beneficiation stage produces ferrovanadium. The major application of ferrovanadium (FeV) is as an alloy addition in high strength low alloy (HLSA) steels. The major market for these steels is in the pipeline industry. In summary, five stages of beneficiation have been identified.

South Africa is a major world producer of both the saleable raw material and the stage 1 beneficiation product. South Africa, including the Republic of Bophuthatswana, accounts for nearly 70% of world production of which, Highveld Steel and Vanadium Corporation (HSVC) is responsible for half. In contrast to this dominance, South Africa is a minor producer of ferrovanadium. Highveld Steel and Vanadium Corp produce approximately 300 tons of ferrovanadium annualy for use in the domestic steel industry. This represents just over 1% of total world production.

This project investigates the factors determining the feasibility of beneficiation of vanadium pentoxide to ferrovanadium in South Africa.

It is stressed that the existence of large vanadium bearing ore deposits does not automatically lead to the conclusion that domestic beneficiation would be economically feasible. Other production cost elements or exogenous factors may prove to be a determining factor in feasibility of this project.

The methodology used to evaluate the proposed beneficiation project is a discounted cash flow analysis in the form of net present value (NPV) and internal rate of return (IRR). A sensitivity analysis is conducted to ascertain the effect that changes of model variables have on these decision making criteria. The capital budget techniques of net present value and internal rate of return are calculated on the assumption that an independant producer wishes to establish a greenfield ferrovanadium producing facility.

Structurally, this report is divided into six major sections. Chapters 2 and 3 provide background to the vanadium industry. Chapter 2 deals with the applications of vanadium while the extractive metallurgy of ferrovanadium is described in Chapter 3. In Chapter 4 world demand and supply of vanadium is analysed. Chapter 5 addresses the question of the feasibility of beneficiating ferrovanadium in South Africa. The final Chapter integrates the research findings and concludes with a recommendation regarding further processing of vanadium pentoxide.

CHAPTER 2
APPLICATIONS

Approximately 85% of the total vanadium output is consumed in the steel industry (Chapman, 1989:28). The remainder is consumed as a catalyst in the production of sulphuric acid and maleic anhydride, and in the non-ferrous metals industry. Figure 2.1 shows the percentage end-usage of vanadium.

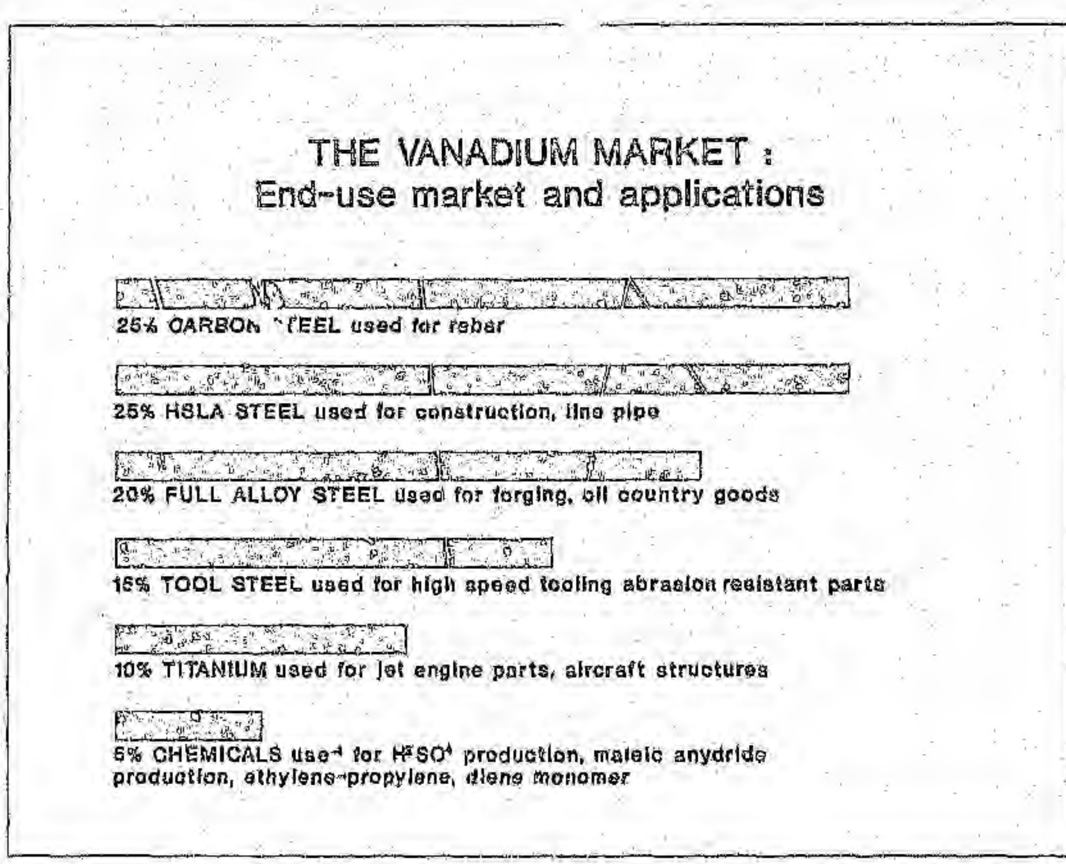


Figure 2.1

2.1 STEELMAKING

Steels principally contain iron and carbon and several other minor alloying elements. The different mechanical properties of steel are determined by its microstructure and by the presence of alloying elements.

The microstructure of steel is controlled by heat treatment. When a steel is heated to a temperature in the range of 430oC to 800oC a homogenous phase known as austenite is produced. The rate of cooling of austenite determines the different mechanical properties of steel. Slow cooling produces pearlitic steels which are soft and exhibit limited ductility. Faster cooling produces bain...ic steels which are harder and tougher than pearlite. Rapid cooling produces martensitic steels where the carbon and alloying elements are very finely distributed. Martensitic steels are the hardest and toughest types of steel.

The value of vanadium in iron and steelmaking is based largely upon the following properties:

(i) The smaller the grain size of the whole mass of steel the greater the hardness and toughness of that steel. Vanadium is a strong carbide forming element. These arbide particles in the steel restrict the movement of grain boundaries during heat treatment and this results in the production of a fine grained steel.

(ii) Vanadium is also a strong nitride former which intensifies the case hardening properties of steel.

(iii) Vanadium can enter into solid solution in ferrite (almost pure iron) and to a lesser extent in austenite. This results in an increase in the tensile strength of ferrite and by precipitation in a finely dispersed state it increases both the hardness and toughness of steel.

2.1.1 High Strength Low Alloy Steel (HSLA)

Approximately 25% of vanadium production is used in the manufacture of HSLA structural steels (Chapman, 1989:28). HSLA steels typically contain 1 to 1,5% vanadium (Grohmann, 1990:1). HSLA steels are finding increasing wide applications because of their improved strength to weight ratios. Savings in weight have been obtained without discounting the strength of components. There are a number of well established uses of HSLA steels: Oil and gas pipelines, general structures such as bridges and high rise buildings, earth moving equipment, trucks, trailers and railway rolling stocks. HSLA steels are also finding an increasing number of applications in the manufacture of high strength reinforcing bars.

2.1.2 Dual Phase Steels

These steels exhibit a dual phase structure and are suitable for use in automotive components because of their good formability. Dual phase steels are so called because they consist of islands of hard martensite (about 10 to 20%) set in a matrix of fine grained ferrite. The production of dual phase steels can be best obtained by the use of a continuous annealing production line followed by rapid cooling. Such equipment is expensive, however, the same effects can be obtained with the addition of suitable alloys in the steel.

2.1.3 Tool Steels

Tool steels are steels which are sufficiently hard to be useful as tools. The vanadium carbide particles present promote hardness and strength at high temperatures. It also improves wear resistance and general machinability. In this case, vanadium addition levels can amount to 2% (Gutridge, 1991:*Pers Comm*).

2.2 OTHER METALLURGICAL APPLICATIONS

2.2.1 Titanium Alloys

Titanium is used for many applications, especially in the chemical and aerospace industries. Additions of titanium impart valuable properties such as resistance to corrosion and high strength-to- weight ratios. Unfortunately titanium loses strength to a marked degree and develops creep at high temperatures. The properties of titanium can be greatly improved by alloying with other metals of which one of the most valuable is vanadium. The use of vanadium is very important in aerospace titanium alloys. The vanadium is used in the ferrous alloy (Ti_6AI_4V) which is important in supersonic aircraft where the strength-to-weight ratio is of primary consideration. Vanadium imparts to titanium a high temperature strength, a property that is essential to jet engines and high speed airframes.

2.2.2 Chemicals and Catalysts

There is a wide variety of applications for vanadium oxides in the chemical and polymer industries. Vanadium pentoxide is used as a catalyst in the production of sulphuric acid and maleic anhydride. Vanadium is also used to remove sulphur from coal gas in town gas works, and is consumed in the ceramics and glass industries.

2.3 SUBSTITUTION OF VANADIUM

There are few applications of vanadium in metals for which other alloying elements could not be substituted. The substitution of vanadium, niobium, molybdenum and titanium in steels is complex and depends on many factors, both technical and economic; historical practice is also important.

It is primarily in the area of micro-alloyed steels that any real degree of substitution can take place. The strength of HSLA steel is brought about mainly by grain refinement and precipitate strengthening. The three major micro-alloying elements in HSLA steels are vanadium, niobium and titanium. The properties they impart to steel are similar, but the differences are enough that often two or even three elements are used together in one type of steel. Certain mechanical properties in HSLA steels are specified but the chemical composition of the steel is not necessarily determinate. Generally any combination of alloying elements or physical treatment can be used providing the desired characteristics are obtained. In these types of steels, these elements are partially, if not wholly, substituable.

A sharp increase in the price of an alloying material, particularly when coupled to a constrained supply, encourages steel producers to use substitute materials, or to develop methods of minimising the consumption of that alloying material.

At present there is no known substitute for vanadium in aerospace titanium alloys. In most chemical industry uses, there are no acceptable allernatives to vanadium oxides or chemicals. For example, vanadium catalysts for sulphuric acid manufacture are cheaper and more effective than the alternative platinum based catalyst.

CHAPTER 3
THE EXTRACTIVE METALLURGY OF FERROVANADIUM

3.1 MANUFACTURE OF FERROVANADIUM

The manufacture and uses of vanadium master alloys are more important commercially than that of the pure metal. This arises owing to the fact that vanadium readily reacts with and absorbs oxygen, nitrogen, hydrogen and carbon. It is thus difficult and costly to produce pure vanadium metal. Furthermore the presence of these impurities renders the vanadium metal to be brittle. The master alloys on the other hand are easier and cheaper to prepare and they are less affected by the presence of the impurities.

Ferrovanadium is produced by the reduction of fused vanadium pentoxide, by means of carbon, silicon or aluminium. It must be noted that the aluminothermic reduction process covered in subsection 3.1.2 will be discussed in greater detail in Chapter 5.

3.1.1 Carbon Reduction

Reduction with carbon is conducted in a submerged-arc electric furnace of high specific power. The furnace usually has a rectangular cross section, using either two or three electrodes arranged in line. These electrodes create a high energy reduction zone. The charge consists of roasted ore or commercial vanadium pentoxide, coke, steel scrap and fluxes. The ferroalloy produced has the following approximate specifications: 33 to 42% vanadium, 3 to 5% silicon and 3 to 3,5% carbon (Duke, 1983:164).

This process has been superceded by other methods because the high carbon content of the alloy is undesirable for most applications. A similar method is, however, used by Union Carbide for the manufacture of their proprietary additive Carvan (85% vanadium, 12% carbon, 2% iron) (Duke, 1983:164).

3.1.2 Aluminothermic Reduction

This process accounts for the majority of ferrovanadium production as it is the simplest and easiest production method. This process is characterised by the following reaction:

$$10Al + 3V_2O_5 \rightarrow 6V + 5\ Al_2O_3$$

This reaction is strongly exothermic and once it has been initiated it can both melt the iron required to make up the alloy, and allow for the effective separation of the alloy and the high alumina slag.

In its simplest form the aluminothermic process is undertaken in an open top ignition hearth lined with magnesite bricks.

The charge consists of a technical grade vandium pentoxide, aluminium, iron or steel scrap, and a flux. These materials are then crushed and thoroughly mixed in the mixer. The charge is then fed into the hopper of the igniting chamber from where it is conveyed to the igniting hearth through a water cooled chute (Schoukins, 1991: *Pers Comm*).

At the beginning of smelting a small quantity of charge is transferred to the bottom of the hearth and then this is ignited by means of a special mixture consisting of aluminium grains and barium peroxide. When the focus of the reaction is sufficiently dispersed, loading of the main charge is started. The charge is fed uniformly as it is smelted (Schoukins, 1991: *Pers Comm*).

The temperature and the rate of reaction can be controlled by adjusting the feed rate and the particle size of the materials, and is especially dependant upon the size of the aluminium. The finer the aluminium powder the faster and more spectacular is the reaction. Some producers prefer aluminum granules to powder because these give a slower and more sedate reaction. The normal duration of the process when a charge containing 500 to 600 kg vandium pentoxide is smelted, is 10 to 15 minutes (Duke, 1983:166).

The passage of vanadium into the alloy amounts to 92 to 95%. A part of the vanadium pentoxide inevitably remains in the slag. Taking this fact into consideration the aluminium reduction of vanadium is often carried out in a closed electric furnace, in which the electric current is switched on after the end process. The remaining vandium pentoxide in the slag is further reduced by adding aluminium. After the 1.5 hour operation both alloy and slag are discharged from the furnace (Schoukins, 1991; *Pers Comm*).

The prepared alloy is crushed and thoroughly cleansed of slag. Ferrovan, a dilute vanadium alloy, is produced by the aluminothermic reduction of vanadium bearing slag.

3.1.3 Silicon Reduction

In this route the reductant is a high grade ferrosilicon containing 75% silicon. Silicon is not a powerful reducer of vanadium oxides, thus a two stage process is required.Technical grade vanadium pentoxide is smelted with ferrosilicon, lime and fluorspar to give an impure ferrovanadium containing about 30% vanadium but undesirably high silicon. The slag carries 0,4 to 0.9% vanadium. The primary metal is refined with vanadium pentoxide and lime in a second step and the secondary slag is returned as part of the charge to produce primary metal (Duke, 1983: 165).

In the USSR a single stage smelting process used to produce ferrovanadium called VD1 which contains approximately 40% vanadium. The charge consists of vanadium pentoxide, ferrosilicon, aluminium, iron scrap and lime (Hess, 1989: 44).

In the past Foote Mineral Company used a two stage silicon process to manufacture their proprietary additive Solvan. This additive contained 28% vanadium, 3,5% silicon, 3,8% manganese, 2,8% chromium, 1,25% nickel and 0,1% carbon (Hess, 1989: 44).

In the first stage, vanadium bearing slags are smelted with silica, a flux and a carbonaceous reductant in a submerged-arc electric furnace. A vanadium silicide alloy containing about 20% silicon is produced. This is then reacted with molten vanadium slags, using lime as a flux to produce Solvan (Duke, 1983: 165).

CHAPTER 4
WORLD DEMAND AND SUPPLY

Vanadium like any other product is subject to normal commercial influences, not the least of which are the laws of supply and demand. In recent years the vanadium market has been volatile and this may be ascribed to changes in the determinants of demand and supply.

4.1 METAL SUPPLY

Metal supply is defined as the amount of metal that a producer wishes to sell at a given price. Metals originate from ores extracted from mineral deposits. Where joint production occurs, the resulting metals may be main products, coproducts or byproducts. A main product is by definition so important that it alone determines the economic viability of a mine. Its price is the only metal price affecting the mine's output of ore and main products. When two metals must be produced to make a mine economic, both influence output and they are coproducts. A byproduct is produced in association with a main product or coproduct. Its price has no influence over the mine's main product output. Once processed, and consumed in final goods metals are often recovered and reused after the final goods come to the end of their useful life and are scrapped.

In the mineral sector, one finds basically two different types of markets. The first are competitive markets, where prices are allowed to move to any level required to clear the market. The market is typically characterised by a large number of buyers and sellers. The second major category of mineral markets are markets with administered prices or producers' prices. The characteristics of a producer market are that prices are quoted by individual producers, an individual company often assuming the role of price leader or seller, and prices change less frequently than in a competitive market. When demand is low, companies often discount the quoted price; when demand is high the product is often rationed but sold at the producer price. The vanadium market is a producer market with Highveld Steel and Vanadium setting the vanadium pentoxide price every quarter.

Based on differences between these two markets, Tilton (1990) p oposes that in contrast to the traditional upward sloping supply curve, the supply curve for a producer market is perfectly horizontal, ie. at the producer price the firm is prepared to sell all of its available supplies. In practice though, firms in a producer market also experience increasing marginal cost as output increases. Their supply curves should thus resemble the supply curves of a competitive market. The only distinguishing feature of these markets is that they have the market power to set the price level. Firms in a producer market are thus able to impose price ceilings or floors depending on the te of the market.

The supply of a mineral commodity to the marketplace is a function of the time available to industry to respond to an increase in demand. For example, in the short term (up to three year.) the industry is mining and smelting capacity cannot increase beyond the capacity of existing operations. In the intermediate term (three to ten years) the capacity of the industry can be increased by investment and the development of known deposits. In the very long term (more than ten years) the capacity of the industry may be expanded by the development of deposits discovered as a result of success in new exploration programmes.

4.1.1 Main Product Supply

The short term supply curve showin in Figure 4.1 indicates the quantities of main product production per period that the total industry is willing to provide to the market at given price levels per unit. The curve serves to show that in the short run supply is elastic until supply reaches capacity at which point supply becomes inelastic. The elasticity of supply measures the responsiveness of the quantity supplied to a change in the metal's own price. Main product supply of vanadium originates mainly from titaniferous magnetitites.

4.1.2 Coproduct Supply

Certain vanadium producers are blessed with a coproduct cost structure. For example, dual product iron and vanadium is recovered from Highveld Steel and Vanadium's integrated steelworks. Vanadium slag with V205 content of 25% is recovered from molten iron prior to conversion to steel. The price of the coproduct influences mine output, but so do the prices of associated coproducts. Joint production costs, those necessary for the production of the coproducts are thus shared between these coproducts. Consequently, a coproduct's supply function includes its own price, the price of associated coproducts, its specific costs and joint costs. Coproduct supply curves have the same general shape as illustrated for main products in Figure 4.1.

4.1.3 Byproduct Supply

There are two important differences between the supply of byproducts and the supply of individual or main products. The first is that byproduct supply is limited by the output of the main product. This is because a higher byproduct price does not increase the output of the main product. The second is that only costs specific to byproduct product affect byproduct supply. Joint costs are borne entirely by the main product and thus byproduct supply is often available at lower costs than the same metal from main product supply. Byproduct supply curves have the same general shape as illustred for main products in Figure 4.1, except that the curve is inelastic at the byproduct constraint, which is imposed by main product output in the intermediate and very long run. In the USA vanadium is recovered as a byproduct of uranium oxide and phosphorous operations.

Supply - demand for vanadium
(QT, QP, QC: production quantity - trough, peak and capacity respectively)

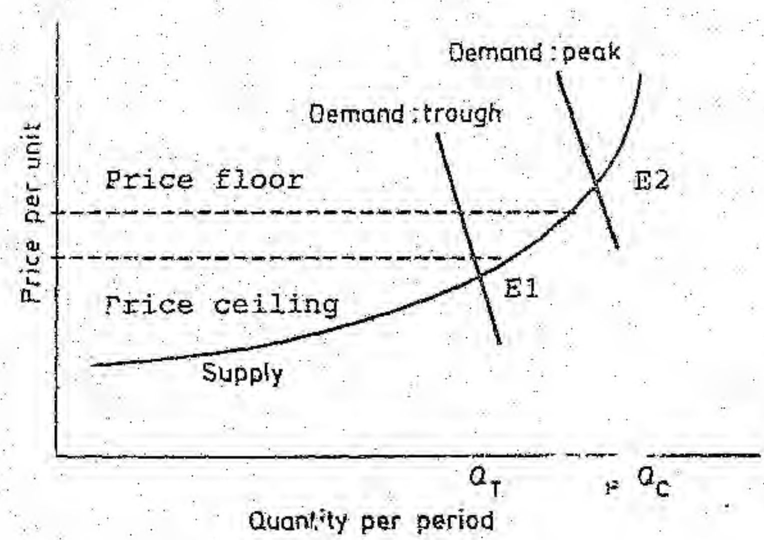


Figure 4.1. Supply - demand for vanadium (Q_T, Q_P, Q_C : production quantity - trough, peak and capacity respectively.

4.1.4 Secondary Supply

Secondary production adds to the supply of metals by recycling new and old scrap. New scrap is generated in the manufacturing of new goods whilst old scrap in turn comprises those consumer and producer goods that have come to the end of their useful lives. Vanadium is found in many oils which comes to the market in several ways: sludges from oil tankers, fly ash from power stations, and spent catalysts used in refineries treating these oils. These residues vary widely in characteristics. Some residues can be beneficiated and processed into fused vanadium pentoxide comparatively cheaply, while others require the same sort of attention as mined ore and slags, and therefore ultimately are not a cheap source of vanadium products.

4.1.5 Total Supply

In order to derive the total supply curve the individual curves for all significant sources must be horizontally summed.

4.2 METAL DEMAND

The demand for metals is a derived demand, since metals are usually consumed as an intermediate product in a final consumer product. Metal costs constitute a small percentage of the final cost of the finished product. For example, the amount of vanadium utilized in tools is quite small, and an increase in vanadium price would have little impact on the demand for tools. As a result of this factor the short run cross price elasticity of demand is very low since it is difficult for the producer of the consumer product to substitute for a high-priced metal, such a change typically requiring a modification to the method of production or a retooling of the process. The other major characteristic of the demand for metals is the high income elasticity of demand.

The main use of metals is in industries whose production is greatly affected by changes in the overall level of economic activity: automobile, transportation, construction and consumer-durables sectors of the economy. Consequently, slight changes in the national level of economic activity cause major changes in demand for metals. The net result of the combination of the characteristics of metal demand, is that the demand curves have a very steep slope. (See Figure 4.1).

4.3 CYCLICAL VOLATILITY

The low short run elasticity of demand and supply results in a cyclic short-term price as indicated in Figure 4.1. When the business cycle is near its peak and demand for metal is high, prices are high and the industry operates near capacity. The dominant company in the producer market historically sets a price ceiling below the market clearing price in this situation. Output is normally rationed amongst favoured consumers. During troughs in the business cycle capacity utilization is low as are prices. The dominant company normally sets a price floor above the market clearing price, but are often willing to offer discounts.

4.4 VANADIUM SUPPLY

The majority of vanadium produced is from titaniferous magnetites, both as a coproduct of iron smelting and as a main product. South Africa is the world's largest producer, contributing approximately 65% of the Western world's vanadium requirements. Unfortunately it is very difficult to obtain reliable figures for the USSR's vanadium production. Before 1988 the USSR was probably the second largest producer of vanadium in the world.

It is proposed by industry specialists that the major role player by the USSR in vanadium supply, is rapidly diminishing (Jacobs, 1991: *Pers Comm*).

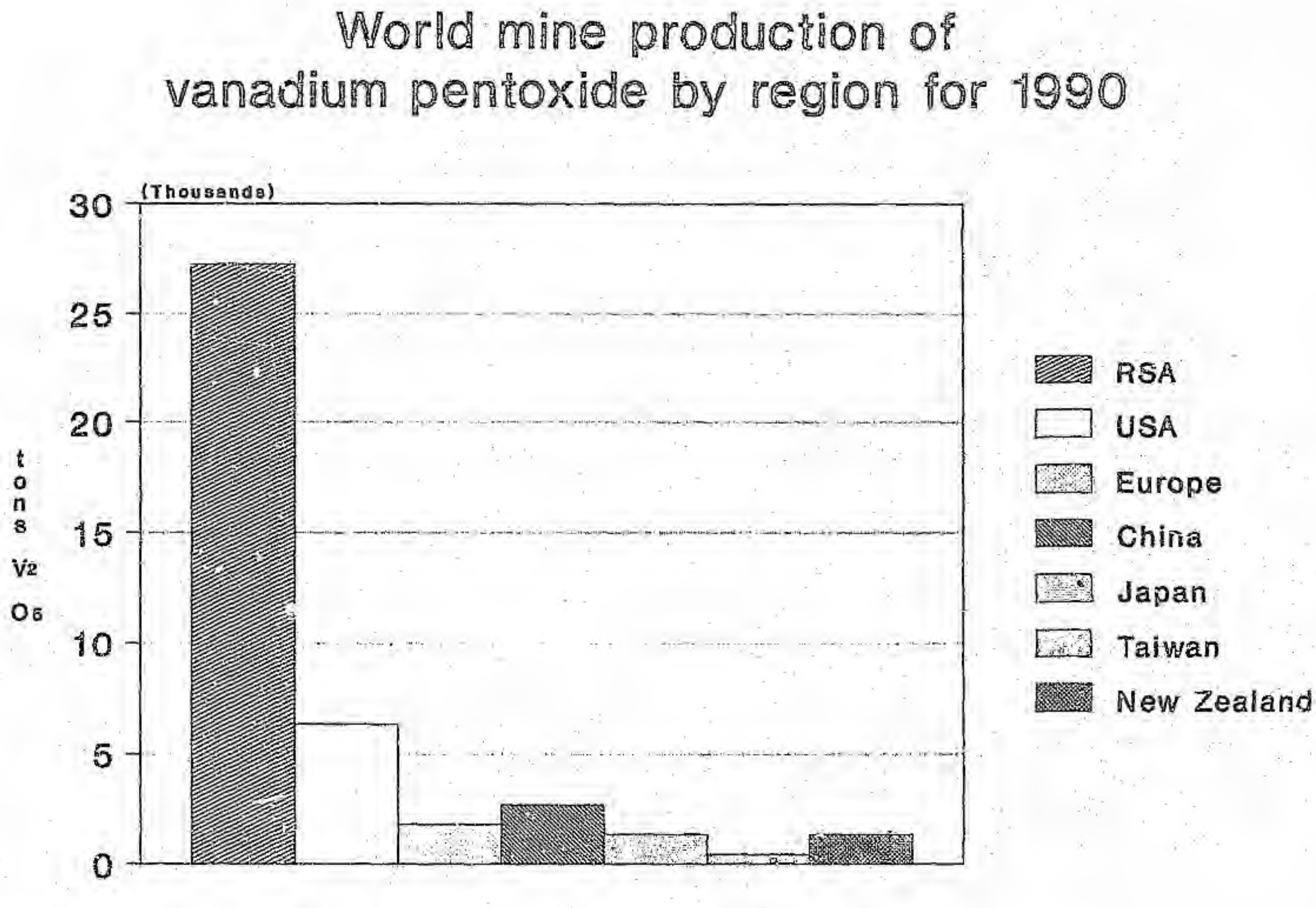
Figure 4.2 shows the world mine production of vanadium pentoxide by region for 1991. The figure is calculated in terms of contained vanadium pentoxide produced. It must be noted that the tonnage estimates used for the USSR and China only represent exports to the West.

Table 4.1 lists the companies active in primary vanadium production in 1991 with their capacities. The South African capacity represents 56% of the total Western capacity.

Table 4.1 Companies active in primary vanadium production in 1991 with their capacities

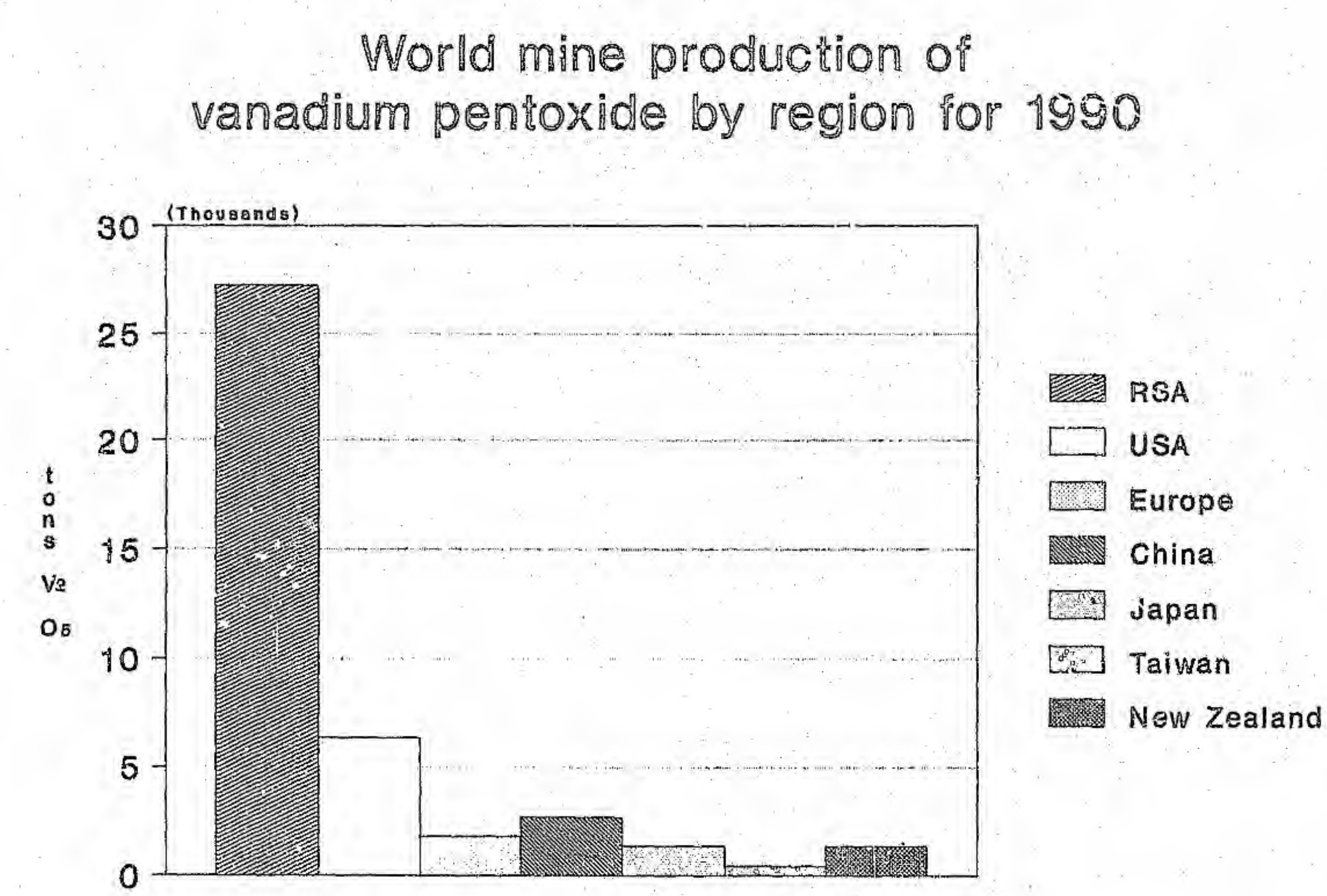
	METRIC TONS OF VANADIUM PENTOXIDE	
	Production	Capacity
SOUTH AFRICA		
Highveld Steel and Vanadium	16783	16783
Vantra	2268	8165
Vametco	4536	4536
Transvaal Alloys	1814	1814
USKO	1814	3629
USA		
Stractcor	1360	4082
Gulf	907	1360
Amax	1360	2268
Kerr McGee	1814	1814
Umetco	-	3629
Other Residues	907	907
EUROPE		
USSR Slag	907	907
Residues	907	907
OTHERS		
China	2722	5443
Japan	1360	1360
New Zeland Steel Slag	1360	2722
Others	454	1360
TOTAL:	41273	61686

Source: (Gutridge, 1991: *Pers Comm*)



Source: Gutridge, 1991: Pers, Comm

Figure 4.2



Source: Gutridge, 1991: Pers, Comm

Figure 4.2

4.5 FERROVANADIUM PRODUCTION

In contrast to South Africa's dominant position in the production of vanadium pentoxide, it is a minor producer of ferrovanadium. Germany, USA, Austria and Japan are the major producers of ferrovanadium.

Figure 4.3 shows the estimated ferrovanadium production by country in 1990. Minor ferrovanadium producers are excluded.

The specific details of the world's ferrovanadium producers is discussed below.

4.5.1 Argentina

Argentina imports most of its vanadium pentoxide from the USA. Stein Ferroaleaciones Sorcifa operates electric reduction furnaces for the production of ferroalloys at Lujan de Cuijo in Mendoza.

4.5.2 Austria

Treibacher Chemische Werke AG has been a long standing consumer of South African vanadium bearing slags. It is one of the largest ferrovanadium producers in Europe, with an annual capacity of 4000 tons of ferrovanadium.

4.5.3 Belgium

The Sadacci Division Sadacem produces ferrovanadium at the Langerbruggekraai plant near Gent. Estimated capacity is 2000 tons p.a. of ferrovanadium.

4.5.4 Brazil

Brazil has an installed capacity of approximately 2600 tons pa of ferrovanadium. Output is shared between five producers:

(i) Cia Paulista de Ferro - Ligas
(ii) Electromahur SA
(iii) Prommetal SA
(iv) Fermoligas Metalurgicas SA
(v) Centroligas - Produtos Siderurgicos Ltda

4.5.5 Canada

Masteralloy Products Ltd, a subsidiary of International Minerals and Chemicals Corporation, uses the alumino-thermic process to produce approximately 900 tons of ferrovanadium per annum.

4.5.6 Czechozovakia

The sole producer, Minsek, uses USSR slag as a starting feedstock for the production of ferrovanadium.

4.5.7 France

Historically France has been a major producer of ferrovanadium. Output was controlled by Pechiney Electrometallurgy, a subsidiary of Pechiney Ugine Kuhlmann. Production of ferrovanadium ceased in 1987.

4.5.8 Germany

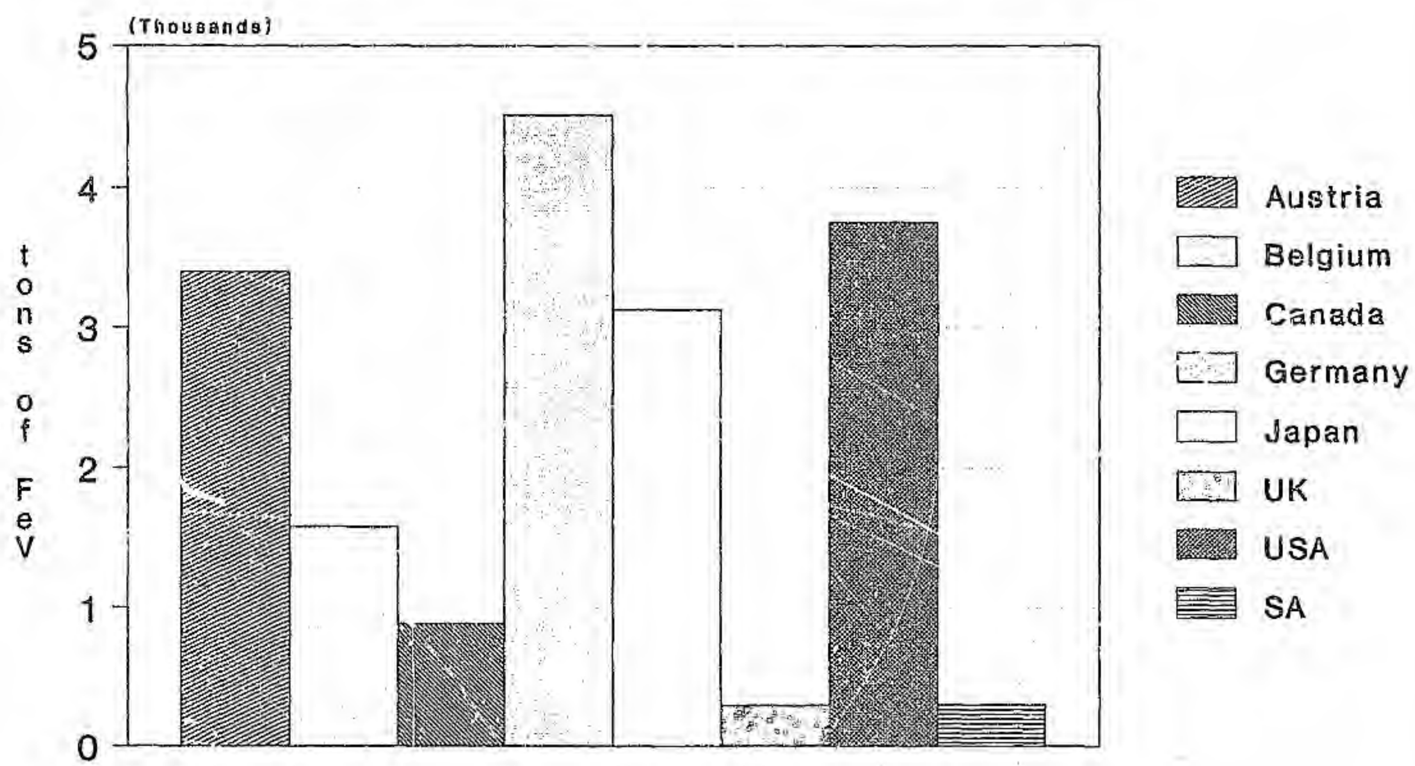
Germany is the largest importer of vanadium ores and concentrates in the world. The imports originate from China, USSR and South Africa. These raw materials serve to supply the large domestic and export market.

Gesellschaft per Elektromettallurgic MGH (GFE) is one of the major vanadium pentoxide producers in the world. Most of the raw material used is vanadium slag of South African origin. A large proportion of pentoxide produced is furthered processed by means of the alumino-thermic process to ferrovanadium. The company has a capacity of 4000 tons p.a of ferrovanadium.

Hermann C. Stark produces many ferroalloys including ferrovanadium, ferromanganese, and ferrotungsten.

Like Hermann C. Stark, Otavi Minen und Eisenbalm Gesellschaft is a multiple ferroalloy producer.

Estimated ferrovanadium production by country in 1990



Source: United States Bureau of Mines, 1991
South African Minerals Bureau, 1991

Figure 4.3

4.5.9 Japan

Although not a major player in the vanadium pentoxide market, Japan is a large producer of ferrovanadium. In 1990 Japan produced approximately 3200 tons p.a. Output is shared between four producers: Nippon Denko (35%), Taujo KoKo (30%), Kurimura Kinzoku Kogyo (20%), Japan Metals and Chemicals (15%).

4.5.10 United Kingdom

Ferrovanadium is produced in the UK by three companies. The raw materials used are imported vanadium pentoxide and vanadiferous slags.

Murex uses the alumino-thermic process to produce ferrovanadium. The metallurgical plant can treat slags, residues and ashes. Estimated capacity is 15000 tons p.a ferrovanadium. It is doubted, however, that this capacity is solely devoted to the production of ferrovanadium.

London and Scandinavian Metallurgical Company is a subsidiary of Metallurg Incorporated of New York. The company has a capacity of 600 tons p.a ferrovanadium. However, as in the case of Murex actual production is not to capacity as it produces a wide range of ferroalloys.

Ferroalloys and Metals Limited is a multiple ferroalloy producer which has a capacity of 200 tons p.a..

4.5.11 USA

The major producers of ferrovanadium in the United States is Strategic Minerals Corporation (Stratcor) and Shieldalloy Corporation. Other producers include: Foote Mineral Company, Elkem Metals Company and Reading Alloys Incorporated.

4.6 ANALYSES AND SPECIFICATIONS OF FERROVANADIUM

Detailed specifications and analyses of ferrovanadium supplied by various leading producers are given on Table 4.2.

In addition to the standard ferrovanadium (80% vanadium), proprietary vanadium additives are also produced.

4.6.1 Nitrovan

Nitrovan is a vanadium nitrogen compound which can be used for adding vanadium to some types of steel where increased nitrogen content can enhance the effect of vanadium. The compound contains 6 to 7% nitrogen, 10 to 12% carbon and 78 to 80% vanadium (Duke, 1983: Appendix IV).

4.6.2 Ferovan

Ferovan is a dilute vanadium alloy which contains a proportionate blend of silicon, manganese and chrome. This blend is reported to impart high solubility and vanadium recoveries in molten steel. The compound contains 4 to 5% manganese, 6 to 7% silicon, 6 to 7% chromium and 42 to 44% vanadium (Duke,6 1983: Appendix IV).

4.6.3 Carvan

Carvan is essentially a vanadium carbide containing approximately 82 to 87% vanadium and 10 to 15% carbon. It is also claimed to impart higher solubility and vanadium recoveries than ferrovanadium (Duke, 1983: Appendix IV).

4.6.4 Solvan

Solvan is a high silicon form of ferrovanadium containing approximately 28% vanadium, 4% silicon, 4% manganese and 3% chromium (Duke, 1983: Appendix IV).

Detailed specifications and analyses of ferrovanadium supplied by various leading producers are given in Table 4.2.

Table 4.2. Analyses and Specifications of Ferrovanadium 1984 - 1988

COUNTRY	COMPANY	V	C	Si	Al	S	P	As	Cu
Austria	Treibacher	78-84	0.25	1.0	1.0	0.10	0.05	0.05	
Belgium	Sadacem	78-85	0.25	1.0	1.0	0.05	0.05		0.01
		78-85	0.25	1.5	1.5	0.05	0.05		0.01
U.S.A.	Foote Mineral	53.5	0.7	4.0		Mn	0.48	Fe	40.0
	Ferovan	42.0 Min	0.6	5.5		Mn	5.50	Fe	40.0
Canada	Masteralloy Standard	50-55	0.10	1.5	1.5	0.06	0.05		
	Special	75-85	0.10	0.5	1.5	0.06	0.05		
U.K.	Murex	35-45	0.06	0.4	1.1	.015	.015		
		50-60	0.06	0.4	1.1	.015	015		
		70-80	0.06	0.4	1.1	.015	.015		
West Germany	GFE	88-92	0.10	1.0	2.0	0.05	0.06		
		78-82	0.25	1.0	1.0	0.05	0.06		
		58-62	0.25	1.0	2.0	0.05	0.06		
China	Nanjing								
	(V751)	75-85	0.2	1.5	3.0	0.05	0.05		
	(V752)	75-85	0.3	2.0	4.0	0.10	0.10		

Source: Ferro Alloy Manual, 1989: 224.

4.7 DEMAND

Vanadium consumption varies in direct proportion to the amount of steel smelted and to the proportion of alloy ste[illegible] total volume of steel produced.

Table 4.3 shows estimated consumption of vanadium (all forms) by region for the year 1991. Figure 4.4 shows the estimated consumption of ferrovanadium by country.

Table 4.3 <u>Consumption of vanadium pentoxide (metric tons of V_2O_5)for 1991</u>

Region	Tons V_2O_5	
	Vametco	USKO
Western Europe	12700	12247
Eastern Europe	2720	1814
USA/Canada	9979	9072
Japan	5897	5897
Others	7258	35834
TOTAL:	38554	35834

<u>Source:</u> Gutridge, 1991 (Vametco); Jacobs, 1991 (USKO)

The demand for vanadium is inextricably linked to the level of crude steel production. Approximately 85% of vanadium consumed is in the manufacture of steels and a large proportion of this is used for the production of HLSA steels. Steel consumption is in turn related to population size and economic wealth, thus it is these exogeneous factors which are the major determinants of demand.

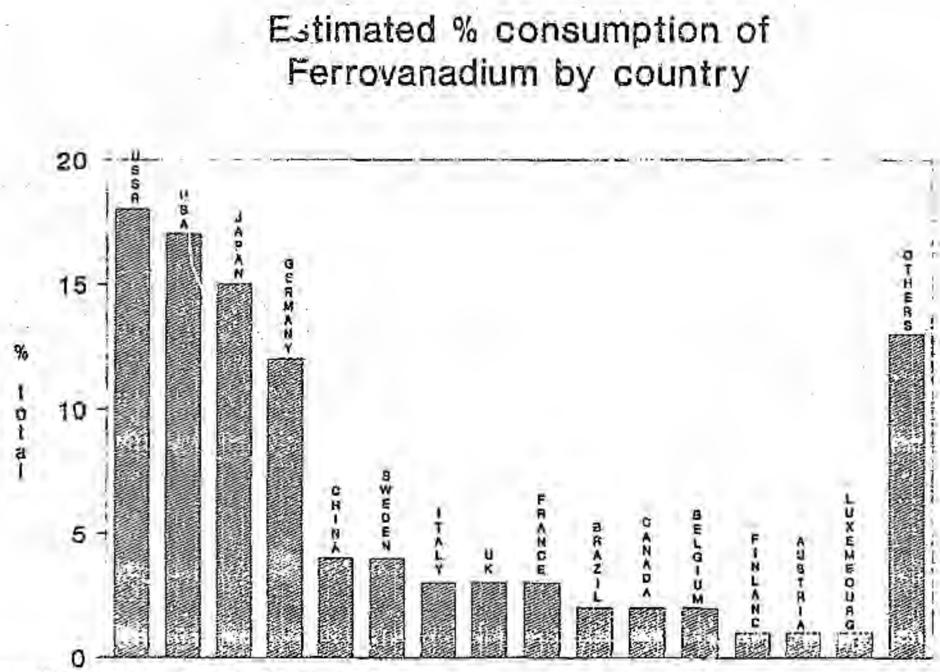
Table 4.4 and Figure 4.5 highlight the relationship between crude steel production and vanadium consumption. A number of salient features are eminent from this chart:

(i) Vanadium consumption is strongly correlated to crude steel production.

(ii) The world crude steel market is cyclical.

(iii) The peaks and troughs of the cycle of vanadium consumption appear to be accentuated. This feature may be ascribed to two factors. Approximately 15% of vanadium consumed is used in the manufacture of tool steels.

The demand for tool steels is, in turn, related to the rate of investment in new plant and equipment. Such expenditure is highly cyclical. Secondly, it is postulated that during times of peak steel demand, steel producers are less cost conscious with output being the main objective. It is in these times that more vanadium is consumed relative to niobium. Generally, it may be said that niobium is more difficult to use than vanadium and thus the use of vanadium is justified. However, in the case of an economic downswing steel producers search for ways of cutting capacity and decreasing costs. In such instances niobium is substituted for vanadium.



Source: United States Bureau of Mines, 1991
South African Minerals Bureau, 1991
Roskill's letter from Japan, January 1991:4

Figure 4.4

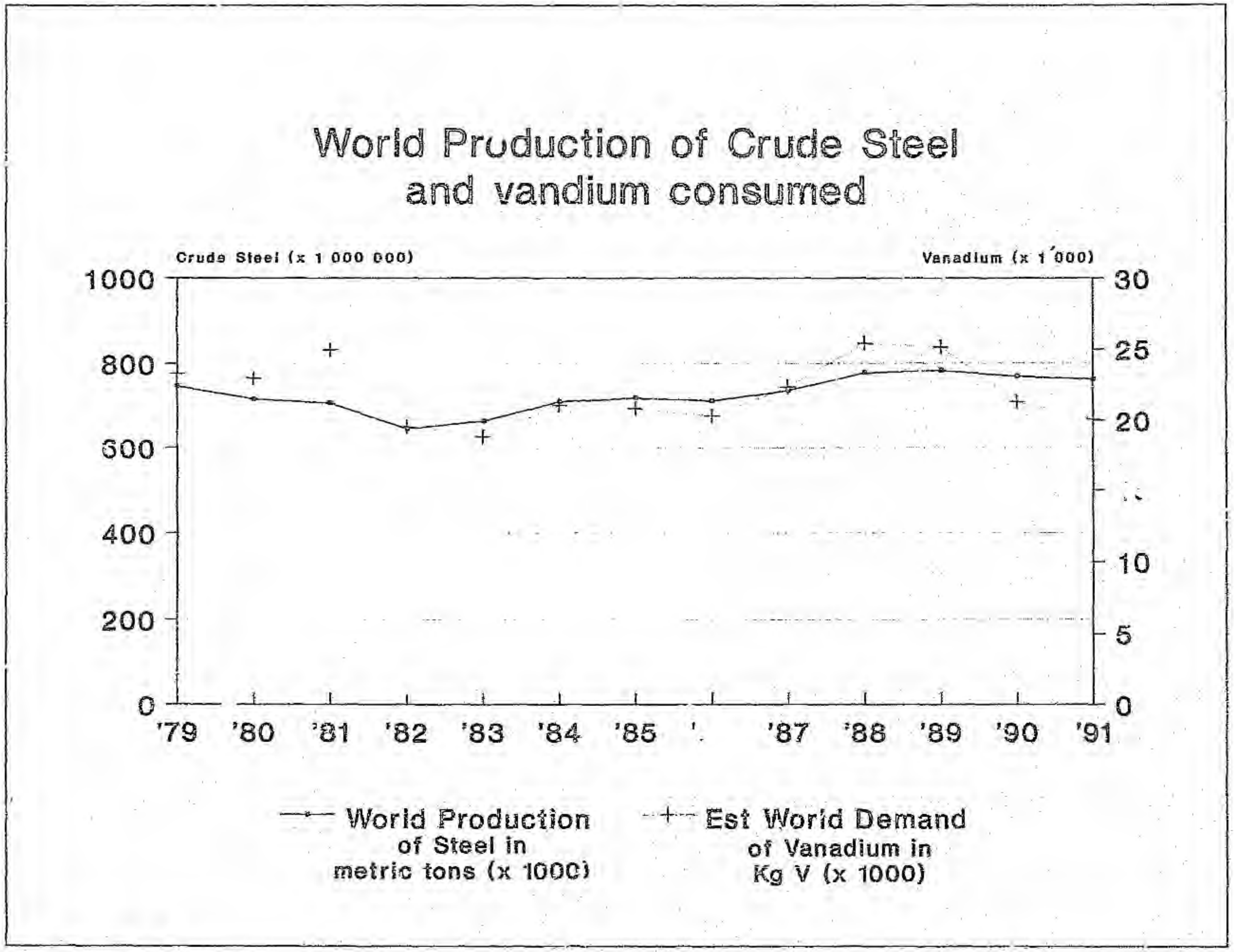

World Production of Crude Steel
and vandium consumed
Crude Steel (x 1 000 000)
Vanadium (x 1 000)
1000
800
600
400
200
0
30
25
20
10
5
0
'79
'80
'81
'82
'83
'84
'85
'87
'88
'89
'90
'91
World Production of Steel in metric tons (x 1000)
Est World Demand of Vanadium in Kg V (x 1000)

Figure 4.5

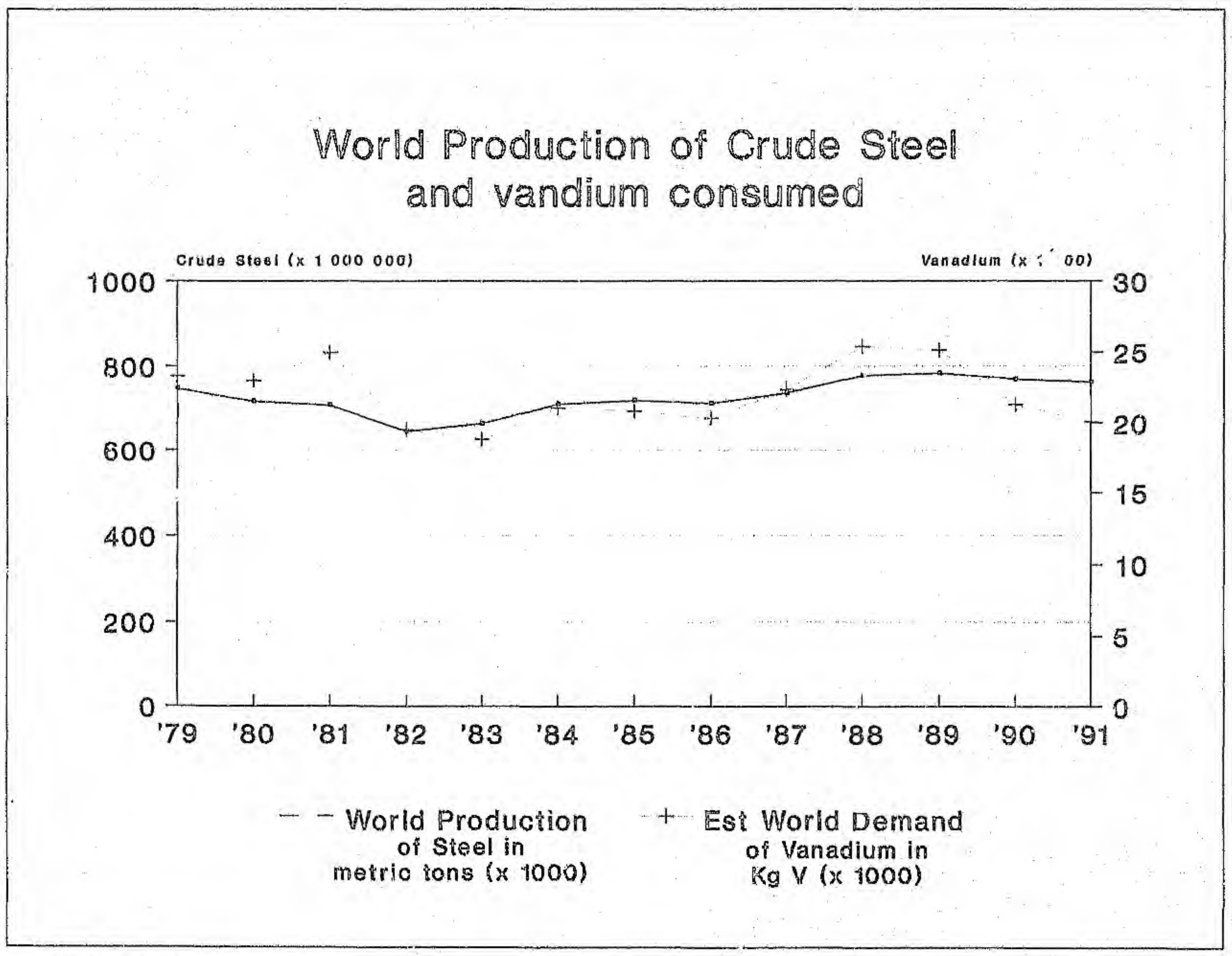

World Production of Crude Steel
and vandium consumed
Crude Steel (x 1 000 000)
Vanadium
1000
800
600
400
200
0
30
25
20
15
10
5
0
'79
'80
'81
'82
'83
'84
'85
'86
'87
'88
'89
'90
'91
World Production of Steel in metric tons (x 1000)
Est World Demand of Vanadium in Kg V (x 1000)

Figure 4.5

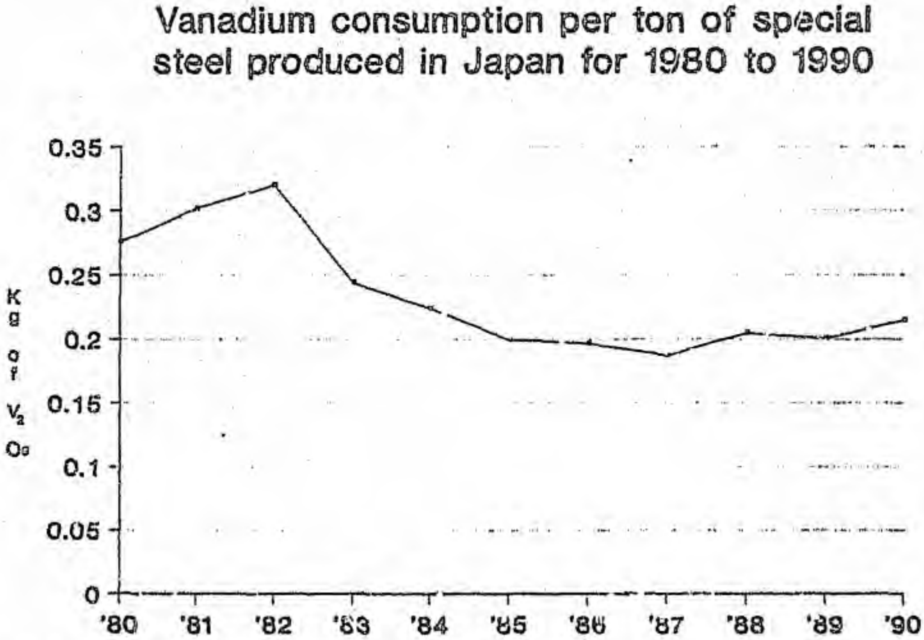
Table 4.4 World Production of Crude Steel and Vanadium Consumed

Year	World Production of Crude Steel (metric tons)	Estimated World Demand of Vanadium (Kg V)	Kg V/100 tons Steel
1979	747 500 000	23 319 000	3,12
1980	717 400 000	23 013 000	3,21
1981	707 948 000	24 945 000	3,52
1982	645 808 000	19 535 000	3,02
1983	664 090 000	18 810 000	2,83
1984	710 954 000	21 080 000	2,97
1985	718 953 000	20 830 000	2,89
1986	713 116 000	20 325 000	2,85
1987	737 000 000	22 353 408	3,03
1988	778 000 000	25 401 000	3,24
1989	783 500 000	25 147 584	3,23
1990	769 400 000	21 337 344	2,77
1991	763 500 000	20 067 040	2,62

Source: South African Mineral's Bureau (1991);
Duke (1983:135);
Ferroalloy Manual (1990:222)

It is evident from Table 4.4 that current consumption has weakened from around 25 147 tons of vanadium in 1989 to an estimated 20 067 tons in 1991. This 20% decline in demand has taken place almost exclusively in the steel industry. Total steel production has, however, only declined by two to three percentage points. It is thus proposed that other exogenous factors are constributing to lower vanadium consumption in the steel industry.

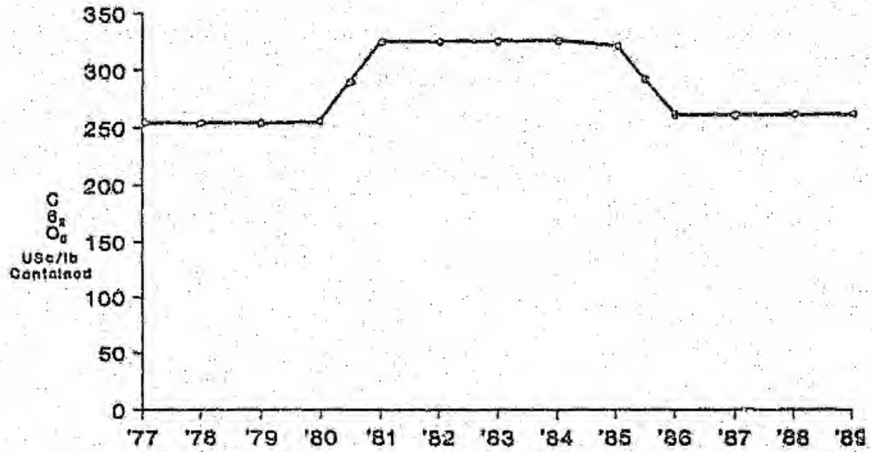
It is shown in Figure 4.6 that the amount of vanadium consumed per ton of special steel produced in Japan is steadily declining. It is assumed that Japan is representative of the Western World's steel industry. The decline in vanadium consumption per ton of special steel produced has been ascribed to the following factors:



Source: Roskill's letter from Japan, January 1991:4

Figure 4.6

Niobium price history



Source: Crowson, 1986 to 1990

Figure 4.7

(i) The substitution of vanadium by niobium. Niobium and vanadium have always been considered interchangeable because of their similar properties as microalloy elements which increase the tensile strength of steel. Over the last decade, the use of niobium has grown at vanadium's expense. For instance a comparison of Japanese consumption of ferrovanadium and ferroniobium between 1980 and 1990 shows that consumption of ferrovanadium has declined by 10%. compared with 78% growth in the use of ferroniobium (See Table 4.5). Such a simple comparison of consumption of the two metals is considered unfair, however, it is clear that niobium has steadily expanded its share of the special steels market.

Table 4.5 Japanese consumption of ferrovanadium and ferroniobium, 1980 to 1990 (tons)

1980	4,668	2,336	7,004
1981	5,140	2,951	8,091
1982	5,493	3,107	8,600
1983	3,991	2.390	6,381
1984	4,338	2,966	7,304
1985	4,038	3,359	7,397
1986	3,479	2.776	6,255
1987	3,346	2,579	5,925
1988	4,054	3,482	7,536
1989	3,875	3,717	7,592
1990 (Jan-Sept)	3,126	3,133	6,259

Source: Roskill's Letters from Japan, January 1991:4

The sharp increase in the price of ferrovanadium in 1989 and the volatility of the market has encouraged steel producers to switch demand to the more stably priced niobium. The Brazilian Arasca mine, Compantiua Brasilena de Metalurgica & Mineracao and Niobic in Canada are the major producers and dominate the market. The Brazilians have promoted niobium through stable pricing which has contrasted with wild fluctuations in vanadium prices (See Figure 4.7).

(ii) The introduction of technology such as controlled rolling and water cooling, along with prior precision in chemical composition, allows greater control over steel micro structures. This can therefore produce steels with properties that could only previously be attained by the addition of alloying elements.

(iii) According to the International Iron and Steel Institute, (IISI), steel production in the USSR and Eastern Europe has declined by almost 30% (Steel Metals Monitor, 1991:5). The USSR and Eastern Europe steel industry has traditionally consumed more vanadium per ton of steel than their competitors in the "Western World". Steel producers in Western Europe, Japan and the USA are more technically sophisticated and profit orientated than Eastern block countries.

In summary, it is clear that the current market for vanadium is oversupplied and this overcapacity would be able to meet anticipated demands for the next decade. Current consumption has weakened from 45 359 tons of V_2O_5 in 1988 to an estimated 35 834 tons of V_2O_5 in 1991. In 1991 production is estimated to amount to 41 000 tons with total capacity estimated to be 61 000 tons of V_2O_5.

4.8 WORLD TRADE IN FERROVANDIUM

Table 4.6 shows recorded exports of vanadium for the years 1986 to 1990. It is clearly evident that South Africa dominates the world export market for vanadium bearing slag and vanadium pentoxide. The major export markets for these materials are Germany, Austria, Belgium, U.S.A. and Japan. Germany accounts for approximately 35% of the export market. These countries are the major exporters of ferrovanadium. In the past France was also a significant exporter of ferrovanadium. Table 4.7 shows estimated trade figures for ferrovanadium for 1991.

Table 4.6. World Exports Of Vanadium 1986-1990 Metric tons of contained V_2O_5

Country	1986	1987	1988	1989	1990
South Africa	29 726	26 251	28 281	29 550	21 732
China	4 700	4 000	4 500	4 500	4 500
USSR	1 800	1 800	1 450	1 450	1 450
Other	2 062	15 016	178	200	150

Source: Minerals Bureau Of South Africa 1991.

Table 4.7 Ferrovanadium Trade, Apparant Consumption, Production and Import Dependance

COUNTRY	IMPORTS	EXPORTS	PRODUCTION	APPARENT[1] CONSUMPTION	IMPORT[2] DEPENDENCE
Austria	177	3 400	3 396	177	0
Belgium	128	1 300	1 582	410	0
Brazil	n/a	n/a	n/a	n/a	n/a
Canada	271	610	889	550	0
Finland	211			211	100
Germany	2 068	2 977	4 511	3 602	0
Italy	800			800	100
Japan	235	25	3 127	3 343	16
Luxembourg					
Korea	492			492	100
Netherlands	113			113	100
S.A.			300	300	0
Sweden	1 097	42		1 055	100
U.K.	565	38	300	827	64
U.S.A.	127	272	3 756	3 900	4
Spain	200			200	100
Switzerland	150			150	100
Yugoslavia	332			332	100
Others	2 500			2 500	100
TOTAL	10 566	8 664	17 861	20 062	

[1]Apparent consumption is production plus imports less exports.
[2]import dependence is net imports as a percentage of apparaut consumption.

Source: Data extracted from the British Geological Services 1991, Bureau of South Africa 1991, USA Bureau of Mines 1991, combined with industry information.

Note: Many of the above figures are approximate estimates only; figures for the command controlled economies are highly speculative.

CHAPTER 5
THE FEASIBILITY OF PRODUCING FERROVANADIUM IN SOUTH AFRICA

5.1 INTRODUCTION

By way of an introduction to the methodology used to evaluate this project, it is appropriate to begin with a brief review of capital budgeting practice, in the mining and mineral beneficiation industries.

Capital expenditure may be classified into two broad categories: replacement capital expenditure and expansion capital expenditure. Replacement capital expenditure would typically comprise the acquisition of an asset to maintain existing production, while expansion capital expenditure may be thought of as expenditure incurred to bring a new venture to account. It is the process of capital budgeting for expansion capital expenditure which is of pertinence to this discussion.

In essence, the capital budgeting decision embodies the allocation of limited capital resources to a portfolio of competing investments. The decision as to how much scarce capital is to be allocated amongst competing investments rests with the level of risk and potential return with such investments. Investment valuation therefore plays a very important role in the capital budgeting decision. Industry specialists believe the most appropriate valuation technique for mining and mineral beneficiation projects are those based on the discounted cash flow methodology. Briefly the valuation technique embraces the following steps:

(i) A commodity price and economic forecast is generated. This will include a proposed marketing plan for the commodity.

(ii) The technical details specific to the potential development are estimated and specified. This provides a basis for estimation and forecasting of capital and operating costs.

(iii) Based on the above information, cash flows are estimated over the life of the project in current money terms.

(iv) Distributable cash flows are then deflated to real money terms.

(v) Based on the discounted cash flow stream the net present value and the real internal rate of return are calculated. The project is then evaluated against a minimum "hurdle" rate which must be achieved to compensate for the risks included in the investment.

(vi) Risk analysis including application of the techniques of sensitivity and simulation.

The technique used to evaluate the feasibility of producing ferrovanadium in South Africa is consistent with the method described above. The structure of this chapter follows the sequential steps of the discounted cash flow analysis.

5.2 ECONOMIC OUTLOOK

The major industrial countries are currently experiencing recessionary conditions. This decline in economic growth has impacted negatively on commodity prices which have continued to weaken over the past year and have currently bottomed at the level prevailing in 1987.

After the recession of the early eighties the OECD economies experienced on average growth rate of 3,7% between 1984 and 1988. The growth rate in 1988 was 4,5% but economic growth in these economies slowed down to 3,3% in 1989 and declined further to 2,6% in 1990. Correspondingly, commodity prices for metals rose 30% in 1987 and by 61% in 1988. Commodity prices then eased by 6% in 1989 and by July 1991 had dropped by a further 11% over the same period in 1990.(Nedbank Economic Unit, August 1991).

The assumption of sustained economic growth in the industrial countries is therefore of prime importance for an improvement in commodity prices. Recent economic indicators from the USA are showing signs of an upturn in the economy, although this has been greeted with scepticism in some quarters. The German economy is likely to grow by only 1,9% in 1992, compared with a forecast of 2,8% for 1991.

The economic growth rate in Japan is forecast at 3,6% in 1991, improving only marginally to 3,9% in 1992. Overall the growth rate, of the economies of industrial countries is forecast to contract further in 1991, with the average expected to be just over 1% and the forecast for next year is 2,8% (Nedbank Economic Unit, August 1991).

A significant improvement in commodity prices is therefore expected only in 1992. For commodity prices to remain at higher levels there will need to be a sustained higher economic growth rate in the industrial countries beyond 1992.

5.3 EXCHANGE RATES

The determination of exchange rates in the free market is normally an application of the laws of demand and supply. The demand for USA dollars arises from USA exports of goods and services, long term and short term capital flows into the USA and the desire of foreign banks, firms and governments to use USA dollars as an international medium of exchange or part of their reserves. Conversely, the supply of dollars to purchase foreign currencies arises from USA imports of goods and services, capital flows from USA and the desire of holders of dollars to decrease the size of their holdings. Central banks, however, often interfere to alter the exchange rate from its free market value.

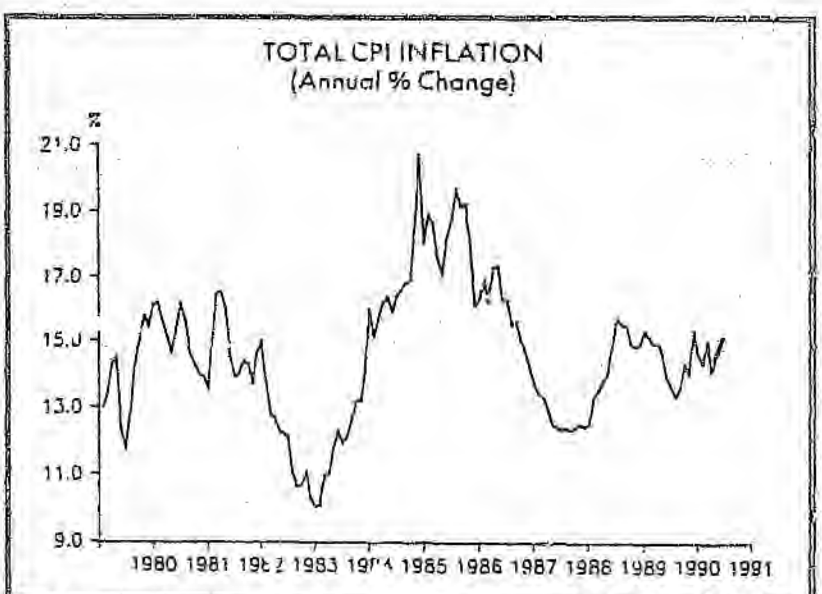
In contrast to the short term where a number of endogenous and exogenous factors influence the exchange rate, the primary determinant of average value of exchange rates over the long run is based on purchasing power parity (PPP) values. The PPP exchange rate is the one that holds constant the relative price levels in two countries when measured in a common currency. For example, assuming that the South African price level rises by 15%, while the German price level rises by only 5 , over the same period, then the PPP value of the German mark then appreciates by approximately 10%. In summary the PPP exchange rate adjusts so that the relative price of the two nation's goods is unchanged because the change in the relative values of two countries compensates exactly for differences in national inflation rates.

Long term exchange rate projections, based on the theory of purchasing power parity, are dependant on inflation rate assumptions of the countries concerned. Ferrovanadium is always quoted in dollar terms, thus the USA and South African inflation rates will be investigated.

5.3.1 **Inflation**

Over the last decade South Africa has experienced double digit inflation (See Figure 5.1). It is believed that the combination of wage increases, credit and [illegible] and entrenched inflationary expectations have all co[illegible]. The annual percentage wage change during the perioc [illegible] 14,6% whilst credit and monetary growth peaked at 27.[illegible] (Finance Week, 8 August 1991:11).

Figure 5.1



Source: Finance Week; 8 August 1991

In 1988, economic activity expanded at the rate of 4,1% and the surplus on the current account of the balance of payments fell to a low of R2,7 bn. This lead to the monetary authorities imposing a restrictive monetary policy. The principal objective of this policy was to reduce the inflation rate to a single digit value by means of limiting the growth in the money supply. Continuing unacceptably high rates of inflation still prevail, however.

The rate of increase in consumer prices, measured over a period of 12 months, increased from 13,3% in July 1990 to 15,3% in November 1990, to fluctuate around this level until June 1991. Similarly, the rate of increase in the total production price index over periods of 12 months accelerated from 10,3% in July 1990 to 15,8% in November, but then fluctuated downwards to 14,1% in June 1991 (Financial Mail, 30 August 1991:30). It thus appears that the Reserve Bank is losing the fight against inflation. It must be noted however, that traditionally the impact of high (or low) interest takes a long time to work its way through the macro-economic system and finally to be reflected in the behaviour of the inflation rate.

The precise behaviour of the inflation rate over the next 20 years could be affected by various factors such as political determinants, oil prices, the introduction of VAT, climatic trends, fresh produce price movements, import surcharges and growth perspectives.

Political determinants are believed to be the single most important determining factor in future inflation rates (Kriel, 1991: *Pers Comm*). It is optimistically assumed that over the next 36 months an internally and externally accepted peaceful political settlement and the full transformation to a post-apartheid society will be achieved. Secondly, the ANC will adopt an economic policy that is market-orientated and financially responsible for foreign investment and capital to flow into RSA in sufficient quantities.

In the short term there appears to exist a trade off between inflation rate and sustained economic growth. Unemployment is at a level that is grimly distressing in human terms and profoundly alarming from an overall socio-political viewpoint. South Africa has one of the world's worst unemployment rates for a so-called middleincome developing nation. It is thus postulated that in the future the central aim of economic policy will be the attainment of growth instead of ratcheting down inflation.

Overall private sector wages increases are exhibiting a declining trend. However, this must occur as long as a recession continues. The problem is that as soon as the economy picks up, it is believed that the unions will not only demand large wage increases to match the current upswing, but also compensation for their earlier restraint.

The implementation of VAT will fuel the consumer price index , but there should be offsetting benefits in the long term.Based on these factors it is postulated that at best an inflation rate of 12% can be achieved over the next 20 years. The most probable rate would be in the order of 16% (Kriel, 1991: *Pers Comm*). It must be emphasized that this inflation projection is based on an optimistic view of the political developments in this country.

The present inflation rate in the USA is approximately 4,5%. It is postulated that over a 20 year period, an average inflation rate of 4% will be experienced (Kriel, 1991: *Pers Comm*).

Based on these inflation rate projections, it is assumed that on average, the Rand will devalue against the Dollar at a rate of 12% per annum.

5.4 MARKETING

Apparent world consumption of ferrovanadium is estimated to be 20 000 metric tons per annum. It is assumed that the ferrovanadium producer will attempt to capture 7,5% of the world market, which amounts to 1500 tons per annum.
The major markets targeted would be the traditional markets of the industrialised world of which the USA, Japan and Germany are the most important. Skillful

marketing may enable a new producer to get an important foothold in the expanding markets of Korea, Taiwan, Brazil, Venezuela and South Africa. Highveld Steel and Vanadium produces approximately 300 tons of ferrovanadium for use in the local steel industry (Chapman, 1989: 16). The aluminothermic reduction process is executed in ignition hearths, the use of which is regarded to be inefficient and costly in comparison with production via the electric furnace route. It is postulated that the use of the more advanced technology may confer to a new producer a potential advantage in the domestic market. This advantage may be offset, however, due to the fact that Highveld is vertically integrated into the raw material supplying activity. At present Taiwan has no ferrovanadium producing facilities and with a demand of 300 tons p.a. this appears to be a very lucrative market (Schoukins, 1991: *Pers Comm*).

The marketing strategy of the new player in the ferrovanadium market will be to create the perception that it would be a reliable supplier of raw materials to the steel industry. Often reliability of supply of ferroalloys is just as important as offering competitive prices. Initially it may be necessary to offer discounted prices in order to capture a share of the market. A discount of approximately 10% will be offered. It is assumed that marketing costs will amount to approximately 4% of total revenue per annum (based on author's estimates).

5.5 MARKET PROSPECTS

The downturn in the vanadium market was reinforced in 1991 as a result of the world wide recession in the steel industry. The world steel industry has been adversely affected by lower economic growth, slowdowns in investment spending and industrial production. With a large proportion of world production going into alloy steels it is expected that vanadium consumption will follow a similar pattern.

According to the forecasts of the OECD steel committee, steel demand in Western Countries could fall by as much as 4% in 1991 (Engineering Week, 5 April 1991:16). The IISI estimates total world steel production to decline by 0,8% from 769,4 million tons in 1990 to 763,5 million tons in 1991. Iscor, however, forecast total production to decline by 2 to 3 percentage points (Engineering Week, 5 April 1991:16).

Unfortunately, actual figures for alloy steels in isolation from total world production are rarely published, however, the downtrend in vanadium consumption can be observed for example by examining the UK market for high speed steels. Approximately 15% of vanadium consumed is used in the tool steel industry. In 1990 demand for high speed steels decreased in the UK by approximately 5% and a continued slide is forecast (Metals Bulletin Monthly, 1991:42). Downturns in demand were also experienced in the USA, France, Sweden, Italy and Spain, while in Eastern Europe market demand virtually disappeared.

The marketing director, Ba Cehlin, at Kloster Speedsteel of Sweden, predicts that the civil aerospace industry is the only sector that will show any growth in the various end use sectors for high speed steel (Metals Bulletin Monthly, 1991:43).

5.5.1 Demand in the end use sectors for vanadium-containing alloy steels

One of the principal uses of vanadium containing HSLA steels is in the pipeline industry. The pipeline market has in the past been affected by the decrease in demand by USSR to carry gas from the Arctic to Central Europe.

There appears to be, however, potential for increased demand in the piping of sour gas in the North Sea. Sour gas is very corrosive, and thus steels which will resist the attack by sour gas must have a uniform microstructure and have low concentrations of sulphur, phosphorous, carbon and manganese.

Such steels do not have a high strength but with the addition of small amounts of vanadium suitable strengths can be achieved. There also appears to be the potential for increased demand stemming from the reconstruction of oil pipelines in the Gulf area. Overall the pipeline market is predicted to remain stable.

The use of HSLA steels in automobiles is increasing as its use imparts weight reduction and fuel saving. The main Western markets appear to be close to saturation, but it is believed that there may be considerable potential in Eastern Europe.

The construction industry has also been adversely affected by deteriorating international economics with downturns being experienced in Europe, especially the UK. The construction industry accounts for a large share of the market for structural steels and reinforced bar.

Approximately 10% of vanadium consumed is used in the non-ferrous alloy Ti-6Al-4V (6 weight percent aluminium and 4 weight percent vanadium). This is essential to jet engines and high speed airframes.

In the past commercial demand for aerospace metals has been turbulent. Defence demand in contrast has been stable and thus many aerospace metal producers have come to depend on it. Unfortunately the changing political climate has thrown some new variables into defence spending.

The defence budget in the USA was reduced from $291,4 billion in 1990 to $275,6 billion in 1991, which appears to mark the end of the cold war (Metal Bulletin Monthly, 1991:43). The war in the Gulf may, however, result in a resurgence of defence demand for aerospace metals when the USA and its allies begin replenishing their arms stockpile. Only 36 allied aircraft were lost in action during the Gulf war according to military reports. Yet following about 100 000 air sorties, airforces are likely to repair or replace many more engines (Metal Bulletin Monthly, 1991:40).

Commercial demand is also assumed to remain healthy until the end of the century, according to the Society of British Aerospace Company. The company predicts that there will be a significant expansion of aviation in Eastern Europe in the future (Metal Bulletin Monthly, 1991:43).

5.5.2 Medium Term Prospects

The prospects for the vanadium market is closely correlated to the welfare of the world steel industry. According to IISI, world steel production is set to peak at around 782 million tons (Mt) in 1995 (Metal Bulletin, 1990:11). Most of the growth is likely to occur in the developing countries of Asia and Latin America. Demand in the industrialised countries is expected to remain fairly stable.

In Asia, demand is forecast to grow by at least 20% from 75 Mt to a minimum of 90 Mt and a possible peak of 95 Mt. Demand in the developing countries of Latin America is seen to grow at an even faster rate. Demand is expected to be around 37 Mt compared with a base of 30 Mt. The developing countries together would consume some 148 Mt in 1995, compared with 128 Mt in 1990.

In North America, after a long down trend due to improving yields and a decline in the output of steel-consuming industries, the level of consumption would remain around 113 Mt through to 1995. Demand in the European Community and Japan is likely to remain firm. Taking the industrialised countries together, their combined consumption in 1995 is estimated to be around 355 Mt. In the centrally planned economics of the USSR and Eastern Europe, consumption would probably amount to 279 Mt in 1995.

In summary world total consumption of steel in 1995 is estimated to be 782 Mt. If 1995 is a year of particularly buoyant steel demand, consumption could be as high as 828 Mt. Based on this forecast it is predicted that the further secular decline in vanadium consumption will cease. It must be noted, however, that the recovery of vanadium demand will not be substantial. Based on the assumption of 2,62 kg of vanadium consumed per 100 tons of steel produced, approximately 20 48 84 00 kg of vanadium will be consumed in 1995. This represents only a 2 to 3% increase in demand from present levels.

5.5.3 Market Opportunities

Two major strategies may be implemented to increase vanadium demand. Greater product awareness and product innovation may enhance consumption. Most of the growth of vanadium demand is likely to occur in the developing countries of Asia and Latin America. The identification of new applications for vanadium and skillful marketing techniques may further stimulate vanadium consumption in these countries. For example, world demand for vanadium could double if the vanadium redox battery development project proves to be successful (Metal Bulletin, 14 October 1991:99).

The vanadium battery offers numerous advantages over lead acid batteries such as low capital costs, rapid recharging and environmental concerns. Secondly, the major vanadium producers of the world would somehow have to restore the perception of vanadium being a stably priced product.

5.6 REVENUE ESTIMATION

5.6.1 Price History

Historically vanadium has been largely producer priced.Even though the bulk of Highveld production is in slag form,its pentoxide price is seen as the benchmark worldwide with other large producers also indexing some of their sales contracts on this price.All quotations for vanadium pentoxide are in US dollars per lb V_2O_5 content.All quotations for (70-80%V) ferrovanadium are in US dollars per kg. The price of ferrovanadium is pegged to the price of vanadium pentoxide. If the price of vanadium pentoxide goes up by 30c/lb it pushes up the cost of ferrovanadium by approximately $1.00/kg.Although the price of ferrovanadium bears a close relationship to the price of vanadium pentoxide it must be noted that this relationship between the prices of the commodities may be distorted by fluctuations in available conversion capacity and market speculation.Vanadiun is not normally traded upon any of the world metal markets such as the London Metal Exchange. The prices for vanadium pentoxide and ferrovanadium are, however, quoted regularly in certain of the trade journals.Prices of vanadium for Europe and United

Kingdom are published in Metal Bulletin and by Metals Week in the USA.In recent years the international vanadium market has been volatile.Price. for vanadium pentoxide and ferrovanadium for the period 1981 to 1990 is illustrated in Figures 5.2 and 5.3.

5.6.2 Historical Pricing Approach

This approach is based on the review of historical price trends and cycles in relation to past supply and demand. This combined with a judgement regarding future economic conditions provides a basis for investment analysis. Essentially this approach is b d on the premise that historical prices determine the level of future prices. By using standard regres. on techniques, a linear tren. is fitted to the historical price data and future trend is extrapolated.

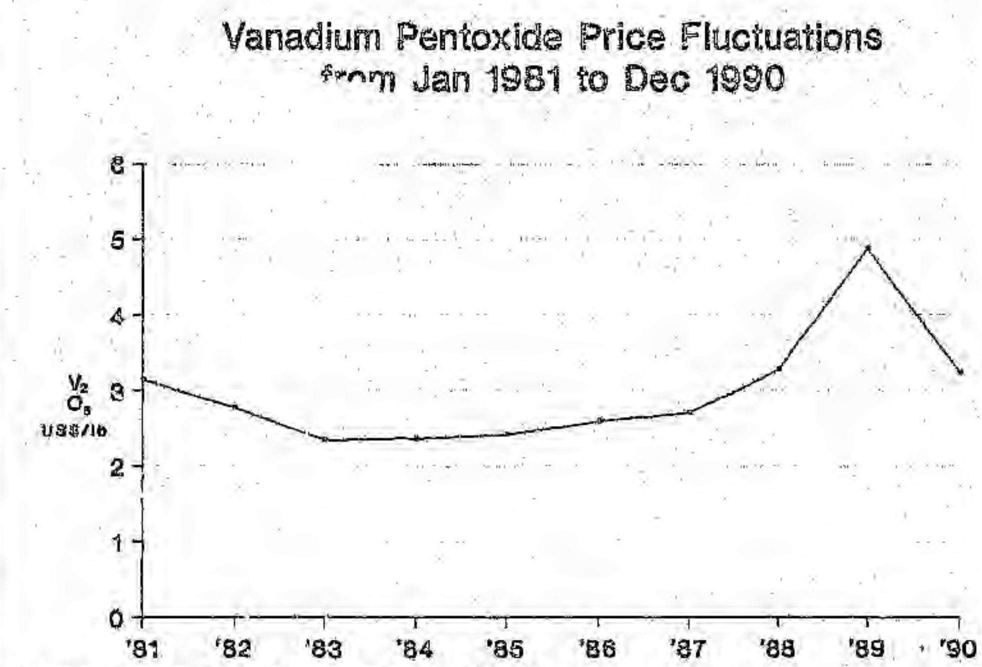


Figure 5.2

Source: Metals Week Price Handbook, 1989:232
South African Minerals Bureau, 1991

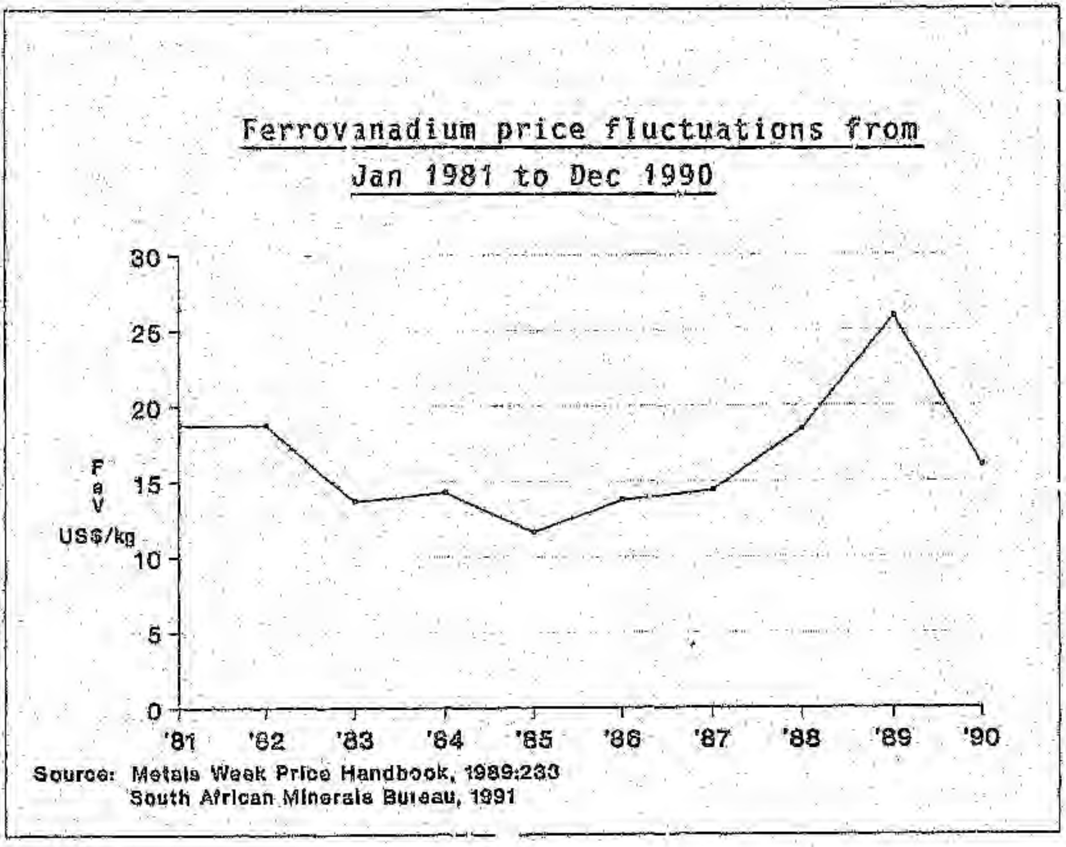


Figure 5.3

A linear trend line has been fitted to the historical price data and is defined by the following equation y = 16.5617 + 0.1571303 × (Origin 1983 - 1984, × units, 1 year, y price of FeV in US dollars per kg FeV). Table 5.1 depicts the price estimates for the years 1991 - 2005 based on the linear trend line.

If the linear trend line is used as the basis for future prices, a base price of $18,60 per kg ferrovanadium for the year 1992 must be used. The base price is assumed to escalate at 1,6% per annum. As a general rule, such historical predictions are unsatisfactory for most important mining investment analyses.

Table 5.1 Price estimates for the years 1991 - 2005

YEAR	PRICE/KG	% INCREASE IN PRICE/KG
1991	18,29	1,6
1992	18,60	1,6
1993	18,91	1,6
1994	19,23	1,6
1995	19,55	1,6
1996	19,86	1,6
1997	20,18	1,6
1998	20,49	1,6
1999	20,80	1,6
,000	21,12	1,6
2001	21,43	1,6
2002	21,75	1,6
2003	22,10	1,6
2004	22,38	1,6
2005	22,69	1,6

5.6.3 Rational Pricing

In this method of price forecasting the cost of competitive producers are reviewed in relation to expected market conditions, to forecast price levels that seem reasonable to bring future supplies into production.

The pricing approach is based on the assumptions that

(i) New productive capacity will be needed on a continuing basis t o offset the depletion of present mines and improved demand.

(ii) To interest investors in new projects, the price must cover not only total cost but must be sufficient to amortize very large investments and pay a competitive rate of return.

The price determined is a long run normalized price and will generally differ from spot prices which reflect short term phenomena, i.e. it is based on self regulating routine of a market economy. The normalized price will in the long run cover the total costs of production and some minimum acceptable rate of return. Rhombus Vanadium Holdings Limited used a base price of \$3,8 per pound vanadium pentoxide with an escalation of 15% to justify the development of a vanadiferous magnetite ore deposit (Rhombus Vanadium Holdings Limited Annual Report 1989:11). In the optimistic case a price of \$4,10/1b vanadium pentoxide with an escalation of 15% was used. The minimum acceptable rate of return was 8% real.

Precious Metals Australia, in turn, used a price of \$3,85 in their feasibility study of the construction of a 2 700 p.a. vanadiumpentoxide plant in the Murchison gold fields (Business Day, 5 July 1991:5).

It may thus be concluded that market sentiment requires a minimum price of \$3,80/1b vanadium pentoxide to justify investment in a primary vanadium pentoxide deposit. A price of \$3,80/lb would imply a minimum price of \$17,7/kg ferrovanadium.

There are some obvious shortcomings in the pricing approach to estimating future mineral prices due to the many imperfections in the vanadium market.

(i) Specifications for the Model Deposit

Mined sources of vanadium raw materials account for only 27% of total vanadium production. These primary mines, which are all situated in South Africa, supply magnetite ore to plants in which only the vanadium is extracted. The major source of vanadium, is vanadium slag which is a coproduct of iron ore operations. Vanadium slag originates from South Africa, USSR and China. Approximately 50% of total vanadium production stems from these operations. The remainder is produced from residues and as a byproduct of other mining operations. Residues vary widely in characteristics but because they are cheap or even valueless at origin, they present quite a severe threat to the mined sources of vanadium raw materials. Secondly, it has been proposed that the cost of vanadium slag is considerably lower than for primary sources. It has been estimated that if the price of vanadium pentoxide is $2,80/lb the market rate for the slag is $1,00/lb.

(This price was obtained from a confidential source and the author's estimates.) It is thus evident that a calculated rational price is very sensitive to the deposit assumed in the modelling process.

(ii) Demand Shifts

To utilize this information for price forecasting, one must decide when to expect growing demand sufficient to utilize existing world capacity and require additional investment in new capacity. The supply of vanadium has kept up with increasing demand throughout the century and at present time is in excess of current requirements. Market forecasts indicate that it is likely to remain so for the next decade.

(iii) Fluctuating Exchange Rates

A factor that may make the price of vanadium particularly difficult to forecast is the fluctuation of the dollar relative to other currencies.

5.6.4 An Examination of Short Run Supply and Demand

Short run supply schedules cover only currently producing and temporary idle mines and exclude any prospective new mines. Mines will continue to operate as long as revenues equal their variable costs of production. In theory, fixed costs are unavoidable and are therefore irrelevant in the production decision. In practice it is very difficult to distinguish between fixed costs and variable costs, and thus we use production costs as a proxy for a short term supply curve in estimating price levels.

Production costs of vanadium pentoxide, for primary vanadium producers are believed to be between $2,50 and $3,00 per pound (Gutridge, 1991: *Pers Comm*).

The production costs for vanadium slags and residues are believed to be lower. It is proposed that revenues should theoretically cover the total costs of production. It is therefore estimated that a minimum price of $2,80 per pound should prevail and this price should be indexed to the Producer Price Index (PPI). This implies that a base price of $14,20 per kg ferrovanadium must be used and this price is escalated at an annual rate, specified by the PPI. In Rand terms the price of ferrovanadium will escalate by 16% as the Rand is expected to devalue by 12% against the Dollar. A more optimistic outlook would predict a price of $15,5/kg ferrovanadium, escalating at an annual rate specified by the PPI.

Although we know that a minimum price of $14,20 per kg ferrovanadium must prevail if ferrovanadium is to be produced, it is quite another matter to accurately predict the timing of this price. As a consequence, short run demand should also be studied to ensure that the proposed investment can survive the near term.

The IISI is optimistic about steel demand in the medium term. The IISI forecasts that peak demand for steel in 1995 is likely to be about 782 Mt.

Based on the assumption that 2,62 kg of vanadium is consumed per 100 tons of steel produced, vanadium demand in 1995 is estimated to amount to 20 488 400 kg of vanadium. This represents a 2 to 3 % increase in demand in relation to present levels. A gradual increase in the price of vanadium is thus expected in the near future.

5.7 TECHNICAL ANALYSIS

The aluminothermic process reduces vanadium pentoxide to metallic vanadium by aluminium metal. The addition of iron scrap produces a ferrovanadium of the required vanadium content. The process can be carried out in ignition hearths without the use of external heat, however, it is most commonly produced in an electric arc furnace. In this way rather less aluminium is required as the reductant and a better recovery of vanadium from the slag can be achieved.

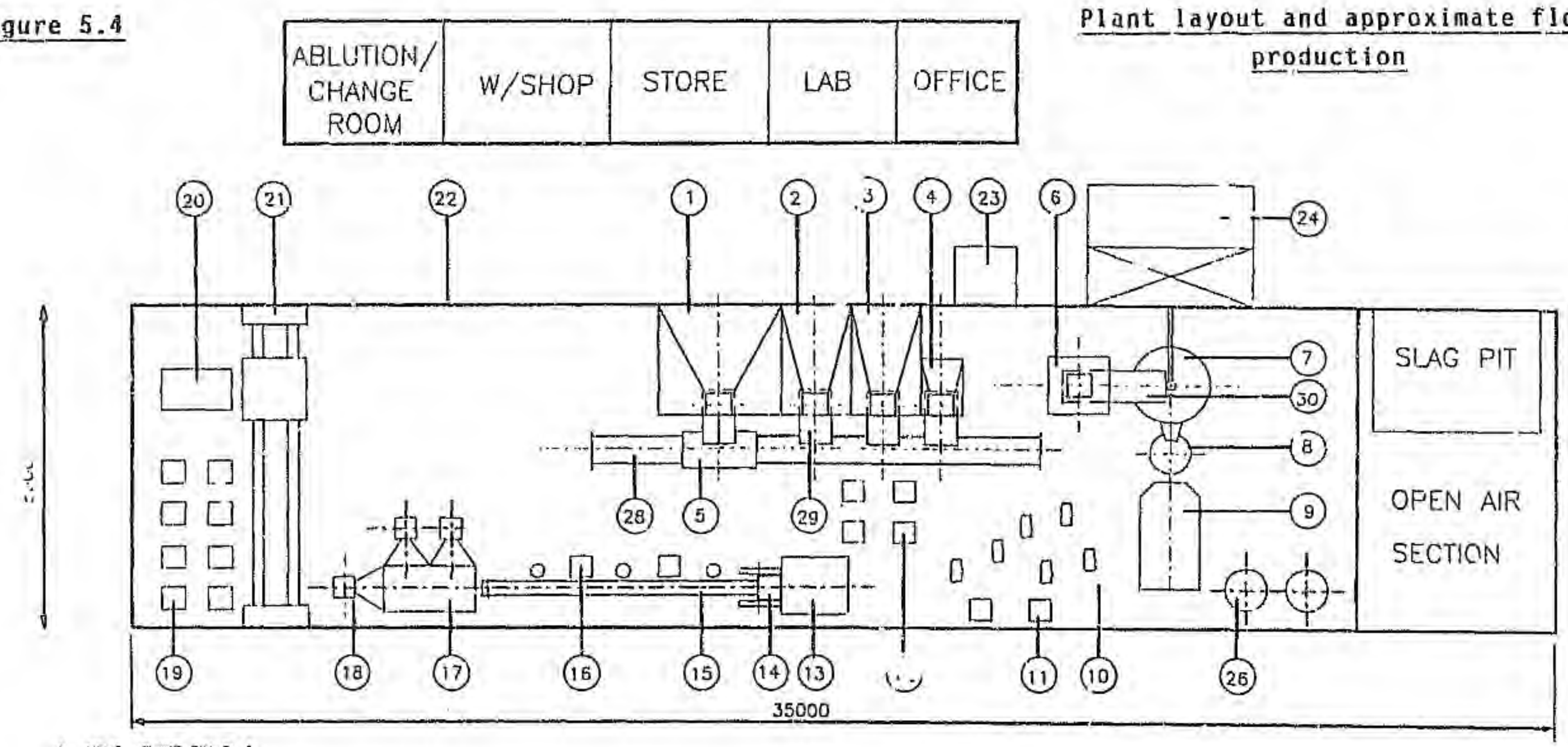
The plant layout and the approximate production flow is shown in Figure 5.4. The receptacles mentioned on the drawing are small metal boxes about 700 mm on a side with open top and hinged bottom. Part-processed material is moved through the production stages with these boxes and the overhead crane.

5.7.1 Raw materials: Receipts, Storage and Proportioning

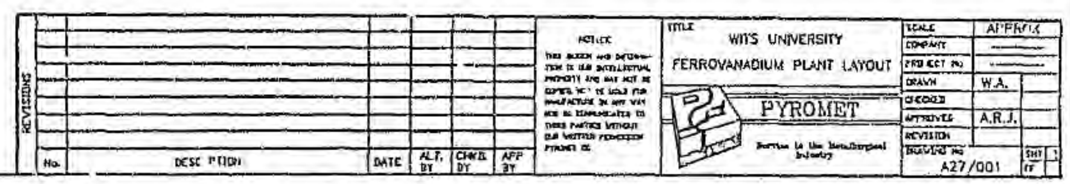
The raw materials are vanadium pentoxide, aluminium scrap, burnt lime, and iron or steel scrap. The process cannot tolerate moisture; thus the material must be stored undercover. These raw materials are thus stored in bins. (See Figure 5.4).

The raw material for each charge batch must be weighed and proportioned into a mixing drum where it is mixed, discharged into a furnace charge bin and transported to the furnace. Each charge has the following approximate composition.

Figure 5.4 **Plant layout and approximate flow of production**



1. V2O5 FLAKE BIN 8m3
2. Al SCRAP BIN 5m3
3. BURNT LIME BIN 5m3
4. Fe SCRAP BIN 1m3
5. TRAVELLING SCALE CAR
6. FURNACE CHARGE BIN 3m3
7. FURNACE VESSEL 2m dia
8. LADLE
9. TAPPING PLATFORM
10. FeV SLAB CASTING AREA
11. RECEPTACLES FOR BROKEN SLABS
12. ANALYSIS GRADED CRUSHER FEED
13. CRUSHER FEED TABLE
14. HAND FED JAW CRUSHER
15. PICKING BELT
16. RECEPTACLES FOR REJECTS
17. SIZING TROMMEL (3 SIZES)
18. RECEPTACLES FOR CLEAN SIZED PRODUCT
19. FINISHED PRODUCT STORAGE
20. VEHICLE ACCESS WITH WEIGHBRIDGE FOR RAW MATERIAL DELIVERY & PRODUCT DESPATCH
21. OVERHEAD CRANE , PENDANT OPERATED 5/1 TON
22. COVERED CRANE AISLE 35m x 8m
23. WATER COOLING PLANT
24. ELECTRICAL EQUIPMENT ROOM (UNDER) CONTROL CUBICLE (OVER)
25. OFFICE, LAB, STORE, WORKSHOP & ABLUTION BLOCK
26. LADLE PREPARATION & REPAIR AREA



Vanadium pentoxide	1 480 kg
Aluminium scrap	768 kg
Burnt lime	512 kg
Iron scrap	128 kg
TOTAL:	2 888 kg

Source: Schoukins, 1991: *Pers Comm*

This produces about 800kg of ferrovanadium containing 80% vanadium. The charges are weighed out for each 90 minute operating cycle.

5.7.2 **Furnace Operation**

A 2MW d.c. electric arc furnace is used. The furnace is charged with the iron scrap and heated for 25 minutes after which the mixed charge is fed in slowly through the roof for 30 minutes. The resultant product is an alloy with a relatively low aluminium content and a slag with a relatively high vanadium oxide content.

In order to promote slag/metal separation the power is maintained for an additional 15 minutes. Additional aluminium is fed into the slag during this period to reduce the vanadium oxide in the slag.

It is assumed that the slag and the metal would be tapped from the same tap hole into a ladle from which slag would be decanted before casting the ferrovanadium. The high value of ferrovanadium would mean that losses of ferrovanadium to the slag must be carefully controlled. Bottom pouring from the ladle may be necessary to control ferrovanadium losses in the slag. The tapping time is approximately 10 minutes, giving a total cycle time of around 90 minutes.

After cooling the slag and ferrovanadium slabs are forwarded for processing. The slag goes to the recycle unit or is dumped or sold as road fill.

5.7.3 Product Handling and Dispatch

The ferrovanadium slabs are broken up into large lumps of a size suitable for the jaw crushers, The broken up slabs are then loaded into a bucket, sampled and stored until the analysis indicates if it has passed or must be rejected.

The acceptable product is crushed in a three stage crusher unit, and set to produce the required product size range, which may vary from one consignment to the next. The sizes are normally run in campaigns, thus the single loading bin is filled with the batch being loaded at the time. The material is then dispatched from the loading bin, and each size range of product is drummed. The material is then sampled, weighed and labelled. The drums are then palletised.

5.7.4 Production Rates

It is assumed that the potential ferrovanadium producer will attempt to capture 7.5% of the world market. This amounts to the production of approximately 1500 tons per annum.

The total cycle time is approximately 90 minutes, which allows 6 charges per day. Approximately 800kg of ferrovanadium is produced per furnace charge. Thus 4,8 tons of ferrovanadium is produced daily which theoretically amounts to 1752 tons p.a. It is conservatively assumed, however, availability will be 85%. Actual production will thus amount to approximately 1500 tons p.a.

Although the technical information is standard, a period of operation with a high rejection rate should be planned for. It is assumed that the preproduction period will be 12 months and that production will amount to 750 tons in the first year of production. Full production will be attained in the following year.

5.8 **CAPITAL COSTS**

Up to the stage of fused vanadium pentoxide, the processing of vanadium bearing materials is comparatively capital intensive. In contrast, during the processing from fused vanadium pentoxide to ferrovanadium 80-90% of the cost of the finished product is related to the raw material input, and only 10-20% to other costs (Sage, 1977:105).

It is estimated that the capital costs associated with a greenfield vanadium pentoxide plant, similar to that operated by Usko, would cost in the order of R300 million (SA Mining, Coal, Gold and Base, Minerals, 1990:20). Usko's plant has a capacity of 9000 tons of vanadium pentoxide per annum. It has recently been announced in the press that Precious Metals Australia intends opening a 3800 tons a year vanadium pentoxide plant in Western Australia. The capital costs associated with this project are estimated to amount to R113 million (Business Day, 5 July 1991:5).

In contrast to these excessive amounts, the capital costs associated with a ferrovanadium plant, with a capacity of 3200 tons of ferrovanadium p.a., only amounts to approximately R5,5 million (Jamieson, 1991: *Pers Comm*). This estimate has been supported by other industry specialists (Schekal, 1991: *Pers Comm*).

The capital cost for a 2 MW d.c. furnace plant is estimated to cost R4,2 million. The equipment list, described in Appendix 1, gives an indication of what is covered by this price. This price excludes land, bringing services to the site, storm water drainage, laboratory equipment, stores equipment, security and access control and taxes and levies.

After allowing for the excluded items a reasonable estimate of total costs would be R5,5 million. Maintenance costs are assumed to amount to R500 000 p.a. These costs are assumed to escalate at a rate equal to 20% p.a..

5.8.1 The Price of Capital

According to certain industry specialists, the industrial environment in which the SA mineral beneficiation industry operates is unfavourable because of the high cost of capital compared with that of other countries. Table 5.2 depicts the results of a survey, compiled by the SA Chamber of Business, on the relative costs of doing business in South Africa (SACOB, 1991:24). It is evident from the table that the cost of capital in South Africa is significantly higher than several other countries. Factors that have contributed to this situation are high interest rates, escalating inflation and high tax rates. Higher yields are also required because of political risk.

Table 5.2 Cost of Capital Comparisons

	SOUTH AFRICA	AUSTRALIA	U.S.A.	JAPAN	GERMANY	FRANCE
Investors Expectations (Earnings yield)	18,3%	8,6%	7,8%	1,9%	6,0%	7,9%
Corporate Tax Rate	50%	39%	34%	32%	50%	39%
Cost of Equity (Pre Tax)	36.6%	14,1%	11,8%	2,8%	12,0%	13,1%
Real Interest Rate	7,0%	11,4%	5,7%	1,9%	5,0%	6,5%
Inflation Rate	14,0%	7,0%	4,5%	1,7%	3,3%	3,3%
Cost of Borrowing (Debt)	21,0%	18,4%	10,2%	3,6%	8,3%	9,9%
Debt/Equity Ratio	33/66	41/49	25/75	71/28	61/39	49/51
Total Cost of Capital	31,1%	14,5%	11,4%	3,4%	9,7%	11,5%

Source: SACOB, 1991:24

It must, however, be noted that this table was compiled before recent proposed amendments in the Taxation Laws Amendment Bill.

Tax deductions for capital goods and property used in the beneficiation of base minerals are to be extended. Currently, industrialists can claim tax deductions only for capital goods and property used in beneficiation processes once they have been put into operation.

The new measures would accelerate write-offs of the cost of machinery, plant and buildings used in beneficiation processes and pre-production interest incurred on those costs. The deductions of depreciation and finance charges will be granted in the tax year in which expenditure is incurred. These enhanced allowances would only, however, be available for plants after the yet to be fixed implementation date.

If these tax breaks do come into effect, it would to some extent reduce the cost of capital in South Africa. The price of capital in South Africa would, however, still greatly exceed the price paid by our major competitors.

Generally mineral beneficiation tends to be highly capital intensive, and thus if growth in beneficiation is to be the policy of the future, "then leveling the playing fields in the price of capital is essential." (SACOB, 1991.25).
It is evident, however, that the capital costs of a ferrovanadium plant are relatively small. It is thus proposed that the price of capital and capital availability is not a determining factor in the feasibility of ferrovanadium beneficiation.

5.9 VANADIUM PENTOXIDE INPUTS

Vanadium pentoxide is the major input cost into ferrovanadium production. Approximately 800 kg of vanadium pentoxide flakes are consumed in the production of 500 kg of ferrovanadium. Based on annual production of 1500 tons of ferrovanadium per annum, approximately 2400 tons of vanadium pentoxide is required annually.

5.9.1 Sourcing of Vanadium Pentoxide

South Africa is the largest pentoxide producer in the world. The vanadium producers in South Africa include Highveld Steel and Vanadium, Transvaal Alloys, Vametco, Usko and Vanadium Technology.

5.9.1.1 **Hig .veld Steel and Vanadium Corporation**

It has been reported that Highveld controls over 50% of the world vanadium market. Highv. ld's total capacity is 25000 tons of V_2O_5 per annum. Highveld produces vanadium slag and vanadium pentoxide at two plants located near Witbank. The ore is received from the opencast Mapochs Mine, near the village of Roossenekal.

The vanadium slag is produced as a coproduct of iron and steelmaking. The magnetite ore is first prereduced and then smelted in a electric furnace. The vanadium slag is recovered from the ore after oxygen blowing of the molten iron prior to conversion to steel. Total vanadium slag capacity is 16 783 tons of V_2O_5 per annum. Highveld has recently decided to spend R10 million at the Vantra division to convert up to 20% of its vanadium slag output to vanadium pentoxide (Financial Mail. 2 August 1991:76).

The Vantra Division produces vanadium pentoxide by the cor ·entional roast leach process. A new large rotary kiln was commissioned in December 1989, which increased Vantra's capacity to 8164 tons per annum. In order to stabilise the world vanadium market, production at the Vantra division was progressively reduced until the end of October 1990 when total capacity was idle. Production recommenced in January 1991.

5.9.1.2 **USKO Limited/Rhombus Vanadium**

USKO started prod· .tion in April 1990 initially at 4000 to 4500 tons per annum V_2O_5 compared with a design capacity of 9000 tons per annum. The planned production of 9000 tons per annum accounts for approximately 20% of present world output. The project represents a joint venture between Rhombus Vanadium and USKO. Rhombus owns an open cast mine near Brits supplying the USKO plant with crushed and milled ore containing 2 % vanadium pentoxide (South African Mining, Coal, Gold & Base Minerals, November 1990:20). This figure compares very favourably with other leading producers.

USKO has suffered prolonged commissioning problems, and is battling to produce the 1500 tons a year it contracted to produce with Rhombus Vanadium. At the start of July 1991, the two companies announced that they were considering a merger of operations. Recent reports in the press (Business Day, 15 August 1991:2) suggest that Highveld Steel and Vanadium is on the verge of buying the merged vanadium operations of these two companies. Analysts believe Highveld's interest in buying the operation is to enlarge its control over local production at a time of oversupply (Business Day, 15 August 1991:2).

5.9.1.3 Transvaal Alloys

Transvaal Alloys is a subsidiary of Norddeutsche Affinerie of Hamburg Corporation. The vanadium is extracted by a roast-leach process at its plant near Belfast. It produces vanadium pentoxide and vanadium chemicals. The company has a productive capacity of 2 000 tons per annum. The ore is mined from nearby surface deposits.

5.9.1.4 Vametco Minerals

Vametco Minerals is a subsidiary of the United States vanadium pentoxide and ferrovanadium producer, Stratcor. Its plant is situated in Bophuthatswana and has a capacity of approximately 4000 tons per annum. The company produces vanadium pentoxide by the roast-leach process, and a proprietary additive known as Nitrovan.

5.9.1.5 Vansa Vanadium/Vanadium Technology (Vantech)

In October to December 1988 Vansa Vanadium commenced production of vanadium pentoxide. Ore reserves at the Kennedy Vale deposits were estimated to be 2,9 million tons at an average grade of 1,9% V2O5 and 1,[illegible] million tons at an average grade of 0,9% V_2O_5. Extraction of vanadium by the roast-leach process was carried out at its plant in Steelpoort. The company had a productive capacity of 4000 tons per annum.

On the 6 November 1990 Vansa Vanadium suspended production of V_2O_5

because of low international prices and increasing production costs. The decreasing demand in the USA and increasing competition in the market was given as the reason for the decision. Vanadium Technology recently purchased Vansa's vanadium assets for R17 million (Business Day, 14 August 1991:2). Vantech is making extensive modifications to improve recoveries, with expenditure estimated to be in the range of R5 to 10 million. Production is planned to begin early in 1992. Annual capacity will be 3000 tons per annum (Sunday Times, Business Times, 8 August 1991:4).

It is proposed that a major barrier of entry into the ferrovanadium market may arise from the reluctance of vanadium pentoxide producers to supply a new and independent producer. A conflict of interest would arise as this independent producer would compete directly with overseas processors, who for many years, utilized South African vanadium raw materials. Historically close co-operation between South African pentoxide producers and overseas processors has existed. The processors have well established distribution networks and have proved to be a reliable source of demand. The new independent producer, however, still has to prove its market reliability. In fear of disrupting established marketing links it is proposed that a domestic vanadium pentoxide producer will be reluctant to supply a new independent ferrovanadium producer.

It has been speculated (Duke, 1983: Appendix IV) that a strong degree of collusion existed between the major producers of vanadium. Highveld Steel and Vanadium in South Africa, GFE in West Germany and Union Carbide in the USA were suspected of such behaviour. The author is of the opinion that some form of market collusion exists between Highveld Steel and Vanadium and Shieldalloy Metallurgical Corporation of New York. In January 1988 Metallurg Inc. and Shieldalloy Metallurgical Corp. merged (Vanadium Minerals Yearbook, 1988:2). Shieldalloy Metallurgical Corp. is the largest vanadium processor in the USA, while Metallurg Inc in turn owned London and Scandinavian Metallurgical Company and GFE of Germany.

The company is also believed to have interests in Treibacher of Austria. These companies have been the traditional consumers of Highveld's slag and pentoxide.

It must be noted that there is no concrete evidence to prove this postulation of collusion and it is based merely on market hearsay. Secondly, it is unlikely that Highveld would supply a ferrovanadium producer, which would compete directly against itself for the 300 tons p.a. domestic market.

If the acquisition of the Rhovan-Usko operation goes through, Highveld will come to control 77% of South Africa's vanadium pentoxide capacity. With these doors closed to the new ferrovanadium producer, very little opportunity exists to source the material from alternate sources. It is highly unlikely that Vametco will supply a producer who would compete directly with its parent company, Stratcor. Transvaal Alloys, in turn, has well established outlets for its vanadium chemicals. The most viable source of supply appears to originate from Vanadium Technology. Vantech is a new consortium of foreign investors, assisted by the Swiss-based Marc Rich Group. It is speculated that the company has negotiated a long term contract with a major end user. For the purpose of this report, however, it is assumed that Vantech will supply sufficient quantities of vanadium pentoxide to the domestic ferrovanadium producer.

The roast leach process is based on proved technology, however, often new vanadium pentoxide producers experience commissioning problems. Vanadium Technology still has to prove to be a reliable producer, and thus complete dependance on this company for raw material supply greatly increases the riskiness of the proposed project.

It is generally believed that the availability of large reserves of ore deposits of superior quality affords South African producers a comparative advantage.

For example, the typical mining grade in the Bushveld Igneous Complex is between 1.5% to 1.8% vanadium pentoxide. This is contrasted to the world average of 0.5% vanadium pentoxide (Grohmann, 1991:1). This statement only holds true, however, when beneficiation is conducted by a firm vertically integrated into the raw material supplying activity. Where th beneficiation firm has to purchase its raw material from another party, it normally pays a competitive market price determined by supply and demand. It is postulated that the non-integrated beneficiation firm will still enjoy a competitive advantage from purchasing domestically supplied raw materials due to the following factors:

(i) A reduction in the price of ore arising from lower transport costs. Table 5.3 shows the breakdown of transport costs for a 20 ton lot vanadium pentoxide. It is evident from this table that a discount of 2.25% will be enjoyed by the domestic consumer due to savings in transport costs.

Table 5.3 Transport costs for a 20 ton lot of vanadium pentoxide destined for any major European port

Railage and Collection	R 1 350.00
Terminal Handling Charges	191.00
Agency Fees	300.00
Ocean Freight[1]	2 707.50
Insurance[2]	77.40
Wharfage[3]	3 125.00
TOTAL TRANSPORT COSTS	R 7 750.90
TRANSPORT COSTS/TON V_2O_5	R 387.55

Source: Medite Shipping (Pty) Ltd, 1991.
Notes:
[1] Ocean Freight 950$ x R2,85 = R2707.50
[2] Insurance 0.02% of 110% CIF, CIF= R351851.85
[3] Wharfage 0.9% of FOB value

(ii) It is common practice for local suppliers of ores to enter into annual sale agreements with regular local customers. The price is usually fixed for the duration of the agreement. It is assumed that the vanadium pentoxide is going to be mainly sourced from Vanadium Technology. A large percentage of the mine's total annual production would be required. It is thus proposed that the ferrovanadium producer could negotiate a discount in the order of 5%, however, a conservative estimate of 2,5% will be used.

(iii) These annual sales agreements are normally negotiated in rand terms and thus are not subject to subsequent exchange rate changes. "The consumer of locally sourced raw materials are to some extent shielded from the volatility of the international commodity and currency markets." (Von Below, 1991: 198).

In summary, the attainment of a supply contract from a vanadium pentoxide producer is regarded as one of the most crucial variables determining the feasibility of this project. It is assumed that Vanadium Technology will supply the vanadium pentoxide raw materials at a discount of 5%, with a world base price of $2.80/lb vanadium pentoxide, the discounted price amounts to $2,66/lb vanadium pentoxide. Based on an exchange rate of R2.85 per dollar vanadium pentoxide, inputs costs are estimated to be R26740.74/ton of ferrovanadium.

It must be noted that it is assumed that the domestic ferrovanadium producer enjoys a competitive advantage from purchasing domestically supplied vanadium pentoxide. This statement does not hold true, however, when the overseas processor uses vanadium slag to produce vanadium pentoxide. The use of cheap slag as a starting feedstock gives this processor a competitive edge over those who buy vanadium pentoxide.

There are only three major plants in the world which can convert slag via oxide into ferrovanadium: GFE, Treibacher and Shieldalloy. These overseas purchasers of slag are, however, under environmental pressures. The cost of storing and disposing of waste product is rapidly increasing.

5.10 ALUMINIUM INPUTS

Aluminium inputs constitute a large proportion of the total raw material costs. Approximately 80kg of aluminium scrap is consumed per 100 kg of ferrovanadium produced. Based on the production of 1500 tons of ferrovanadium, the annual consumption of aluminium scrap amounts to approximately 1200 tons. Usually ferrovanadium producers use aluminium scrap, in the form of shredded used beverage cans, however, aluminium pellets or granules ranging in size from 0.15 to 3mm may be used.

It is contended that the availability of cheap sources of aluminium scrap affords the ferrovanadium producer a competitive advantage in the international market. Unfortunately aluminium scrap is not favorably priced in South Africa, and thus domestic ferrovanadium producers are placed at a competitive disadvantage.

5.10.1 The Aluminium Market in South Africa

South Africa obtains its primary aluminium from the smelting of imported alumina. Aluminium South Africa (Pty) Limited (Alusaf) is the sole producer of primary aluminium in South Africa. The production capacity of 170 K tons per annum (Murray, 1989:67) represents approximately one percent of total world production.

Power costs are the major cost element in aluminium production. Alusaf's present power costs place it in the upper quarter of world aluminium smelting costs. Alusaf has, however, negotiated a discounted electricity price with Eskom for a proposed 430 K tons a year smelter. At these prices the international competitiveness of Alusaf is greatly enhanced.

It is proposed that these prices will now place Alusaf in the lower quartile of world aluminium smelting costs (Sunday Times, Business Times, 14 July 1991: 3). This factor will in turn, enable Alusaf to supply cheaper aluminium to domestic consumers.

The Alusaf producer price for local sales of 99.5% primary ingot is fixed approximately every 12 months. During the period 1971 to September 1989 the price rose at an average annual rate of 14.2% (Murray, 1989:69). The price of R5480 for 99.5% aluminium ingot set on the 4 September 1989 has, however, been unchanged (Business Day, 10 September 1991:19).

Hulett Metals (Pty) Ltd is South Africa's largest aluminium semi-fabricator. Other secondary aluminium fabricators in South Africa include: Non-Ferrous Metal Works (Pty) Ltd, Prime Metal Industries (Pty) Ltd and Le Roux Non-Ferrous Refinery Close Corporation. Production of semi-fabricated goods is almost entirely based on Alusaf's primary aluminium.

5.10.2 Sourcing of Aluminium Scrap

In contrast to the markets of the industrialised world, the domestic market is limited, thus the scrap market is under-developed in South Africa. The geographical dispersion of the population acts as a further constraint.

Aluminium scrap, suitable for the aluminothermic reduction process, may be acquired from Prime Metal Industries at a price of R4,50/kg (Bruick, 1991: *Pers Comm*). Unfortunately, only 1100 tons can be supplied. Hulletts can in turn supply sufficient quantities of suitable aluminium pellets at the following price: 99% Al pellets: R6.35 kg, 95% Al pellets: R4.90 kg (De Atougia, 1991: *Pers Comm*).

5.10.3 International Competitiveness of Domestic Sourced Aluminium Scrap

It has often been proposed that the price of aluminium scrap in South Africa has been the principal barrier to local beneficiation of ferrovanadium.

Scrap has become an increasingly important source of aluminium supply and accounted for nearly 25% of total world supply in 1987 (Roskill, 1988:157). A large proportion of aluminium scrap recovered consists of used beverage cans. The rate of growth in the production of secondary supply has been more than double than primary since 1973/1974. Secondary aluminium is produced mainly in the USA (37 to 40%), Japan (17%) and West Germany (10%) (Roskill, 1988: 158).

The average price paid by scrap consumers in Europe based on a 10 ton lot is estimated to be 1050 US dollars/ton (Metal Bulletin, 5 July 1991:17). Based on an exchange rate of R2 85/US dollars, this amounts to R2993/ton. The cheapest source of domestic aluminium scrap is R4500/ton. The domestic consumer of local aluminium scrap thus effectively pays a premium of 50%.

The local ferrovanadium producer has the option, however, of importing the aluminium scrap. The viability of importing aluminium scrap is examined below. Table 5.4 shows the breakdown of transport costs of importing aluminium scrap. An exchange rate of R2.85/US dollars is used.

Based on a price of 1080 US dollars per ton of baled aluminium scrap, the cost of importing aluminium scrap amounts to R3,37/kg. No import duties are charged (Tariff No 760200). It would thus appear that the importation of aluminium scrap is deemed feasible. If the option of importing the product is taken, the domestic ferrovanadium producer now only pays an effective premium of 12% in relation to that paid by competitors abroad.

It must be noted that the feasibility of importing aluminium scrap is dependent on the prevailing exchange rate and the international market price for aluminium. The price of aluminium scrap closely follows the general trend of primary ingot prices.

Table 5.4 Transport costs of importing 20 tons of aluminium scrap

OCEAN FREIGHT CHARGES	US DOLLARS	RANDS
Ex. NWC Ports, i.e. Rotterdam, Antwerp, Bremen, Hamburg	1390	3961,5
LAND SIDE CHARGES AND TRANSPORTATION TO PWV		
Terminal Handling Charges		191,0
Documentation		18,0
Service Fee		40,0
Hand Over of Container		40,0
Cartage (Full) Terminal to Station		94,8
Rail Ex Durban to Johannesburg		960,0
Cartage (Full) to Client's Premises		307,0
Empty Turn In		57,0
Agency Fees		300,0
TOTAL TRANSPORT COSTS		5969,3

Source: Medite Shipping Company (SA) (Pty) Ltd, 1991
Shipping and General (Pty) Ltd, 1991

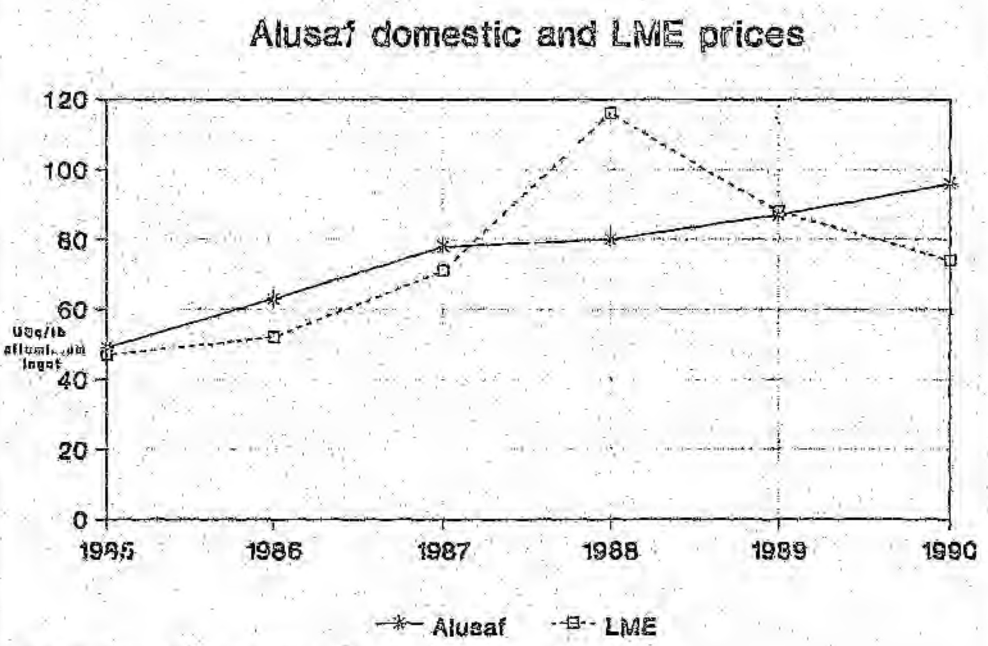
At present the aluminium world market is in a slump. The level of inventories has increased because demand has eased at a time when production has continued rising. It is believed that overseas smelters are selling below cost (Paterson, 1991: *Pers Comm*). Average direct smelting costs exceed 65c/lb, while the swing production technique now firmly entrenched in Europe has costs of 75c/lb (Metals Outlook, 1991:10). The present LME price for aluminium ingot is 58c/lb (Business Day 10, 10 September 1991:13).

At these prices the prevailing Alusaf producer price is uncompetitive. In

1988, however, Alusaf could have sold aluminium ingots as scrap at a margin of R1000/ton in the international market (Paterson, 1991: *Pers Comm*). Figure 5.5 compares the average LME price and Alusaf producer price for aluminium ingots for the years 1985 to 1990. It appears that Alusaf is highly competitive when the market is in an upturn. The converse holds true, however, when a demise in demand is experienced.

It is postulated that the reduced world output and the leveling off in inventories will provide a floor for prices. The price will start increasing in 1992, when economic activity is expected to improve. The peak of the cycle is forecast for 1995. Domestically sourced aluminium scrap may in the near future thus become highly competitive by world standards.

In summary, at present world aluminium prices local ferrovanadium producers are placed at a competitive disadvantage if the aluminium scrap is sourced from domestic suppliers. The importation of aluminium scrap from European markets has been shown to be feasible. The delivered cost of imported aluminium scrap is estimated to be R3,37/ kg. At these costs, the domestic ferrovanadium producer only experiences a 12% cost disadvantage in terms of aluminium imputs. It is noted that in terms of an aluminium market upswing the competitiveness of domestically sourced material is greatly enhanced. A deteriorating Rand exchange rate could acentuate this trend.



Source: Metals Outlook, 1990:10;
South African Minerals Bureau, 1991

Figure 5.5

For the near future it is assumed that the aluminium scrap will be sourced from import markets. Based on a cost of R3,37/ kg, the aluminium input costs per ton of ferrovanadium amounts to R2 896.

5.10.4 **Aluminium Price Escalations**

Aluminium demand is closely linked to the level of economic activity. The current aluminium market is believed to be emerging from the trough of a recession and entering a recovery period.

It is assumed that the base price of 1080 US dollars/ton of aluminium scrap will escalate at an annual rate specified by the inflation rate in the USA. The USA's inflation rate is used as it is the largest secondary producer in the world.

5.11 IRON SCRAP

Approximately 240 tons of dry fine iron scrap is required annually for the production 1500 tons of 80% ferrovanadium. The delivered price for A grade foundary scrap is estimated to be R250/ton (Jacobs, 1991: *Pers Comm*). Based on this price, iron scrap costs amount to R40/ton of ferrovanadium produced. It must be noted that the price of ferrovanadium is based on the vanadium content, with the low value iron considered as free.

5.12 BURNT LIME

Approximately 679kg of burnt lime is used, as a fluxing agent, in the production of a metric ton of ferrovanadium. With estimated annual output of ferrovanadium of 1500 tons, approximately 1018 tons of burnt lime is required per annum. Burnt lime is a high volume, low cost commodity, with the price presently prevailing in the region of R125 to R130 per ton. (Van der Merwe, 1991: *Pers Comm*) The average price for 1990 was a R123/ton burnt lime, whilst the average price escalation since 1980 has been 9%. Using a price of R127/ton of burnt lime, lime material costs amount to R86,2 per ton of ferrovanadium produced.

The South African lime production is controlled by five companies: Anglo Alpha, Blue Circle, Iscor, Natal Portland Cement, Pretoria Portland Cement

5.13 ELECTRICITY

The aluminothermic reduction reaction is strongly exothermic and thus the production of ferrovanadium is not electricity intensive. Approximately 800 Kwh is required per ton of ferrovanadium. This is compared to 8600 Kwh required per ton of contained chrome in the production of ferrochrome (Von Below, 1991a:16)

Average South Africa power costs are the least expensive among fourteen industrialised nations analysed in an international survey. The survey is conducted annually by the National Utility Services and is based on actual prices paid by their clients. National Utility Services operate in eighty countries and provides services to approximately 75 000 business establishments worldwide (National Utility Services,1991:11).

The National Utility Services survey shows that average South African electricity costs are 9,13 cents per Kwh, the next least expensive nation being Canada at 11,9 cents per Kwh. (See table 5.5). Germany's commitment to reduce power station pollution makes it the most expensive electricity producer amoung those countries surveyed. The average electricity cost is 26,82 cents per Kwh. The average electricity costs in the USA is 17,91 cents per Kwh. The USA prices have risen below the rate of inflation, although USA utilities do show an increase overall, attributable to rising fuel costs, restructuring of surcharges and nuclear related costs.

The low electricity costs of South Africa have placed industry and commerce at a competitive advantage in world markets. The Republic's advantage in this respect is being rapidly eroded by consistently high net increases in power costs. The year on year increase in the costs of local power for 1989/1990 was the highest among those surveyed at an average of 16,5% (see Table 5.5). Figure 5.6 shows the annual net increases in electricity costs for South Africa for the years 1984 - 1990.

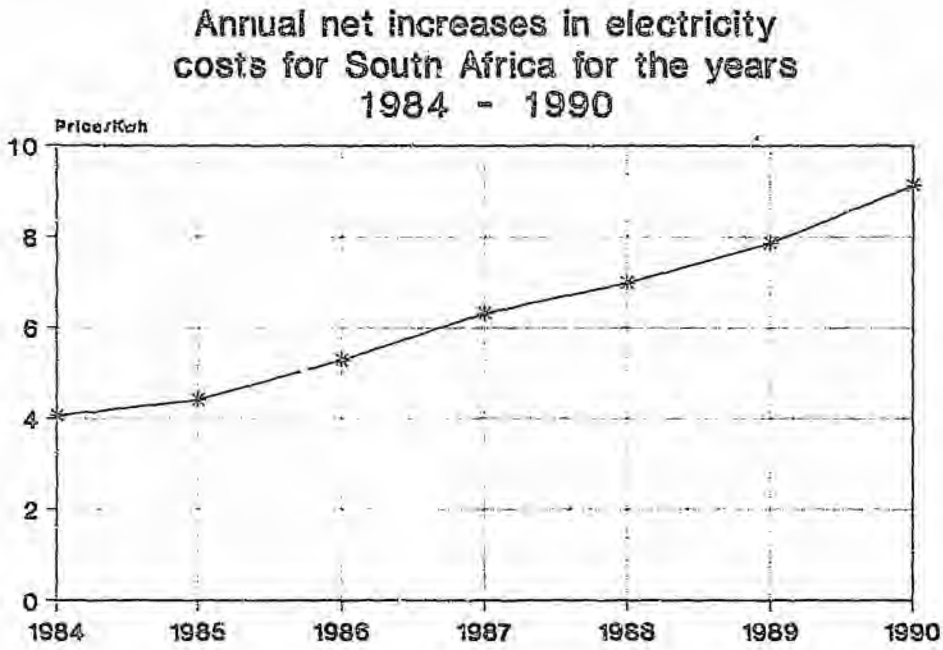


Figure 5.6

The next largest increase of 15,1% occurred in Italy, followed by Finland and Australia with increases of 12,5% and 7% respectively. There is a broad correlation between the electricity price hikes of the various countries surveyed and their rates of inflation.

Table 5.6 illustrates the cost adva e that a potential ferrovanadium producer in South Africa will have over exis producers in terms of electricity cost.

Table 5.6 Electricity costs per ton of ferrovanadium

COUNTRY	R/TON
South Africa	73,04
United Kingdom	157,20
Belgium	162,40
Germany	215,36
U.S.A.	143,28

Source: National Utility Services, 1991:11

Although the South African producer has a cost advantage, it is not significant as electricity costs constitute only a small portion of variable costs.

Table 5.5 NUS INTERNATIONAL ELECTRICITY PRICE SURVEY 1990 LEAGUE TABLE

1989		1990		INC/DEC	ROI
COUNTRY	c/KWH	COUNTRY	c/KWH	%	%
Germany	26,82	Germany	26,92	0,5	2.7
Italy	19,88	Italy	23,00	15,1	6,1
Ireland	19,94	Belgium	20,30	3,8	3,4
Belgium	19,56	Ireland	19,94	0,0	4,1
UK	18,30	UK	19,65	6,9	8,1
USA	17,23	USA	17,91	4,0	5,3
Netherlands	16,40	France	16,76	3,0	3,6
France	16,28	Netherlands	16,05	(2,1)	2,2
Norway	14,84	Finland	15,71	12,5	7,4
Finland	13,97	Norway	15,58	5,0	4,2
Sweden	12,27	Sweden	13,05	6,3	8,7
Australia	11,87	Australia	12,70	7,0	8,6
Canada	11,57	Canada	11,90	3,0	5,4
South Africa	7,83	South Africa	9,13	16,5	14,9

(Figures in brackets indicate price decreases.)

Source: National Utility Services, 1991:12

5.14 LABOUR

In relation to other manufacturing industries the labour intensity in ferrovanadium processing is generally considered to be low.

Table 5.7 below lists the labour requirements, and their relative costs, for a 125 ton per month ferrovanadium plant.[1] Approximately sixty-five people will be employed and annual labour changes, based on 1991 costs, are estimated to amount to R2,23 million per annum. The minimum industry wage for labourers is R4,70/hr and that for artisians is R10,44/hr (Business Day, 1 August 1991:1). Labour costs thus amount to R1.50 per kg of ferrovanadium produced.

Table 5.7 Labour Costs for a 125 ton per month Ferrovanadium plant

STAFF	NUMBER	RANDS
General Manager	1	250 000
Asst General Manager	1	150 000
Metallurgist	1	150 000
Chartered Accountant	1	120 000
Chemist	1	60 000
Buyer	1	45,000
Supervisors	7	490 000
Shopping Manager	1	50 000
Office Staff	2	55 000
Total Staff	16	1 370 000
ARTISANS	NUMBER	RANDS
Artisans(i)	2	69 000
Maintenance Fitters(ii)	3	103 000
Total Artisans	21	1 542 000
SEMI-SKILLED AND UNSKILLED(iii)	NUMBER	RANDS
Security Guards	3	44 000
Weighing and Preportioning	13	225 000
Furnace Operation(iv)	4	37 000
Product Handling(v)	20	315 000
Offloading(vi)	2	51 000
General Gang-stores Cleaning (vii)	2	33 000
Total Semi- & Unskilled	65	[illegible]

[1]It must be noted that the Figures provided are based on the author's personal opinion and on the recommendations of Mr A. Schoukins.

(i) This assumes that the artisians work a 45 hr working week, plus 10 hrs overtime. The hourly wage is R11/hr.

(ii) This assumes that maintenance fitters work a 45 hr working week plus 10 hrs overtime. The hourly wage is R11/hr.

(iii) This assumes that a third of the semi and unskilled workers receive R7,50 per hour. The remainder receive R5,00 per hour.

(iv) This assumes 2 labourers per shift.

(v) This assumes 10 labourers per shift - 2 shift basis.

(vi) This assumes 2 labourers per day shift - 45 hr week plus 10 hrs overtime

(vii) This assumes 2 labourers per day shift - 45 hr week plus 19 hrs overtime

5.14.1 Future Labour Costs

During the period 1980 to 1991 the actual wage rate paid in the metal industries has increased at an average of 13,5% per annum (See Figure 5.7). The sharp increases in salaries and wages has been attributed to South Africa's double digit inflation rate and the desire of the Trade Unions to reduce the White - Black wage gap. Based on historical costs and future projections of the inflation rate, labour costs are assumed to increase at an average rate of 16 % per annum.

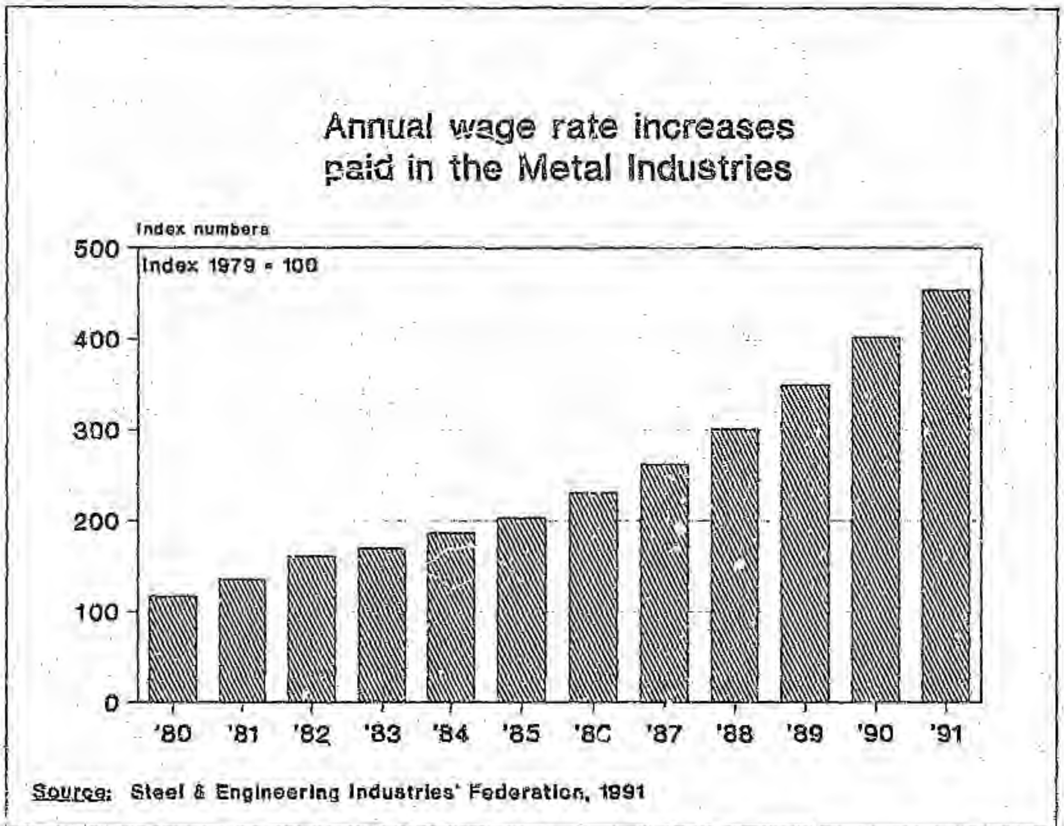


Figure 5.7

'4.2 The International Competitiveness of Labour

Figures reflecting the average hourly wage per metal worker, shown in Figure 5.8, indicate that the hourly wage per employee in South Africa in 1989 was US $ 3,5/hr. Thi s significantly less than US $ 15 to 22/hr in most of the developed countries. On this basis it may be claimed that in terms of labour costs South Africa has a comparitive advantage over its competitors.

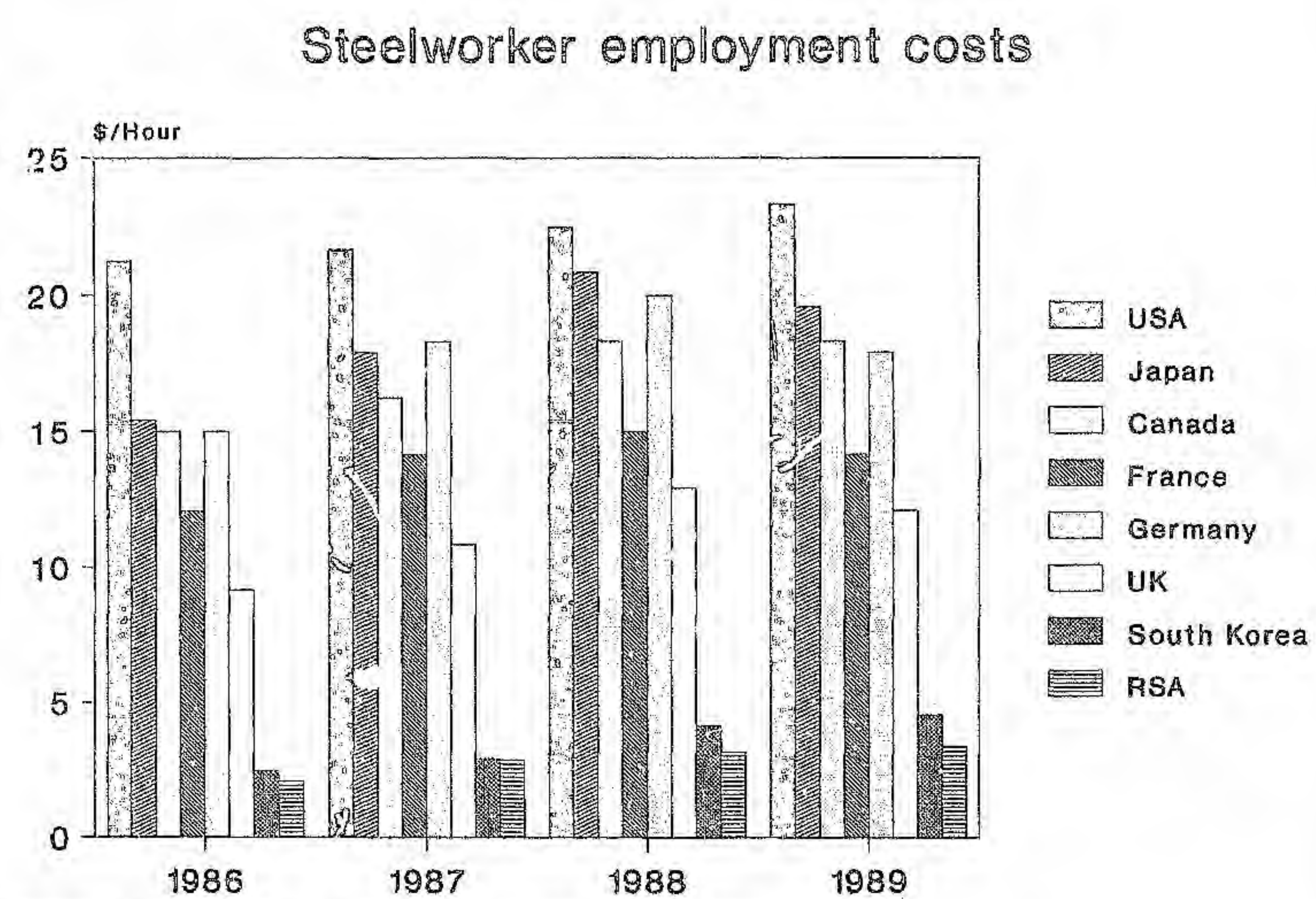
Effective labour costs however, are determined by the combination of the cost of labour and the relative productivity of labour. The productivity of

South African labour compared to our major competitors is low and is improving at a relatively lower rate. It is believed that the labour unrest and the relatively lower level of training of the labour force is responsible for this low level of productivity.

Figure 5.9 shows output per employee in the manufacturing sector. It is evident from this figure that South Africa achieved the least growth in output per worker over the period 1970 to 1988 with output rising by an average 1,9% compared with 5,9% in Japan and 2,7% in Germany and USA.

Figure 5.10, in turn, shows the effective labour costs in nominal national currencies and this figure shows that labour costs in South Africa has far exceded the increases in labour costs in other countries. These increases in effective labour costs in South Africa have, however, been offset by the devaluation of the Rand as shown in Figure 5.11. Based on dollar terms, effective labour costs in South Africa increased by only 5,2% compared to 6,5% in Germany.

It may be concluded that the South African ferrovanadium producer will experience labour costs, that on average, are very similar to that of the major overseas processors. The comparative advantage stemming from the cheap source of labour is offset by low productivity levels.



Source: Steel and Engineering Industries' Federatio 991
The Steel Industry, 1990:21

Figure 5.8

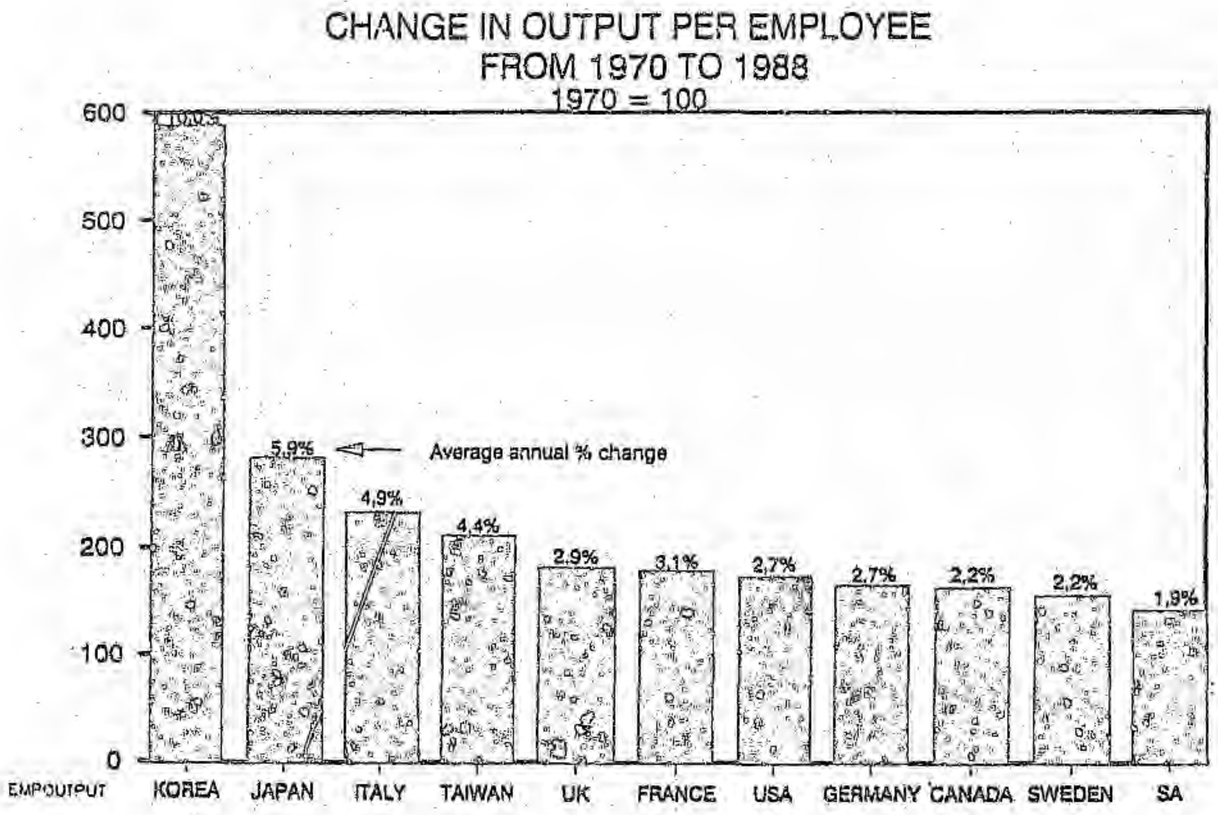


Figure 5.9 Source, SACOB, 1992: 35

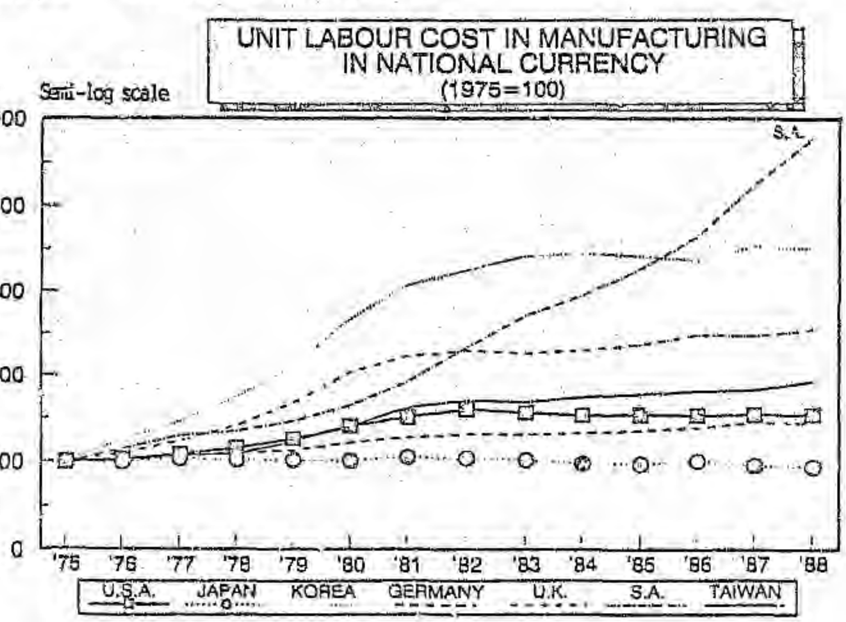
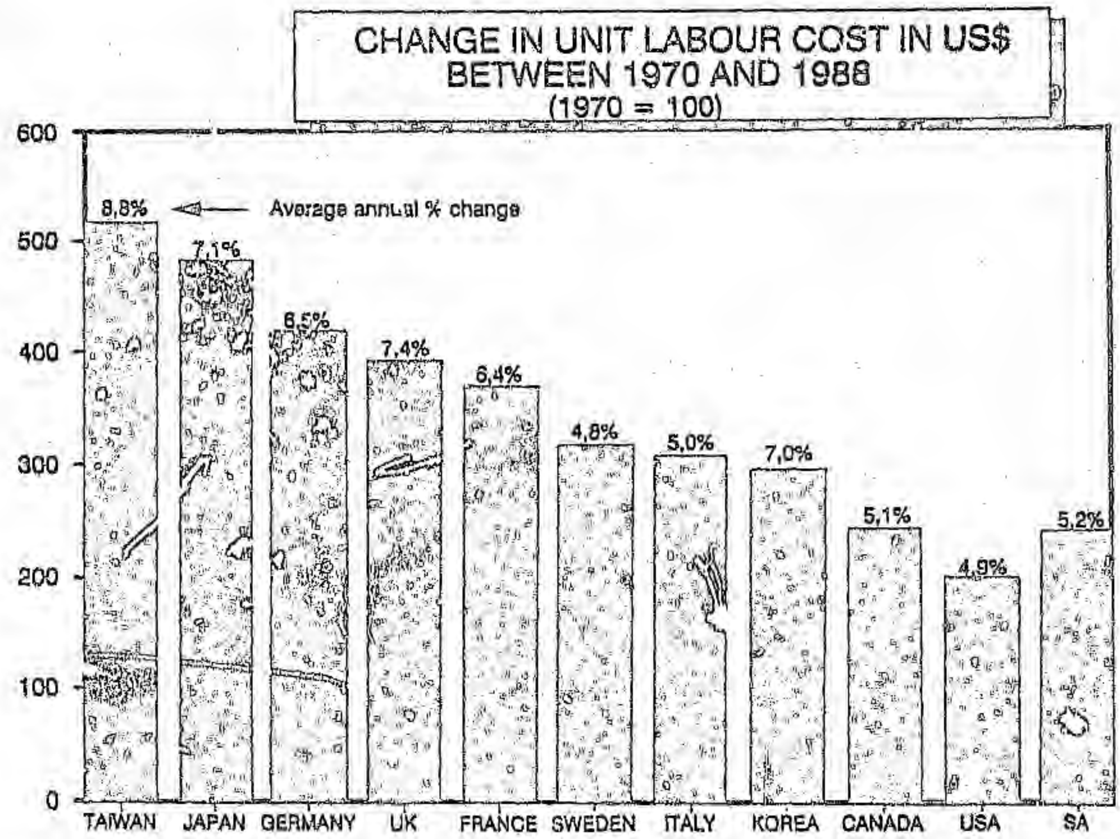


Figure 5.10 Source, Sacov, 1991: 37

Figure 5.11



Source: SACOB, 1992: 37

5.15 TRANSPORT COSTS

Ferrovanadium is a high valued product and thus great care must be taken that no stock losses are incurred during transportation. The ferrovanadium is packed in steel drums and is transported in containers. The transport costs for a 20 ton lot of ferrovanadium destined to any major European port is illustrated in Table 5.8.

Table 5.8 Transport costs for a 20 ton lot of ferrovanadium destined to any major European port [1]

	RANDS
Ocean Freight[2] Railage and Collection Terminal Handling Charges Agency Fees	2 707,50 1 350,00 191,00 300,00
	4548,50
Insurance[3] Wharfage[4]	178,07 7 242,06
TOTAL TRANSPORT COSTS PER 20 TONS OF FeV	11 968,63
TRANSPORT COSTS PER TON OF FeV	598,43

Notes: [1]Exchange Rate: R2,85/$; Base price of ferrovanadium $14,2/kg
[2]Ocean Freight: 950$ x R2,85 = R2707,5
[3]Insurance: 0,02% of 110% of CIF
[4]Wharfage: 0,9% of FOB

Source: Medite Shipping Company, 1991

The transport costs per ton of ferrovanadium to any major European port is R598,43. It is assumed that transport costs will escalate at a rate specified by the prevailing inflation rates.

5.16 ENVIRONMENTAL COSTS

Many mineral-processing activities are highly polluting, and thus costly regulations and restrictions have consequently been imposed on these activities. The production of ferrovanadium is less environmentally hazardous than most mineral processing activities. Dust generated from the aluminothermic process is collected by means of a baghouse collecting system. This dust is normally not recycled but dumped. When using an electric arc furnace the producer has the option to add the dust to the slag and thus eliminating a dust waste product. The slag may be recycled but normally it is dumped or disposed of as road fill. In contrast to ferrovanadium production, the roast leach process, used to produce vanadium pentoxide, is environmentally harmful. Dangerous effluents are emitted into the atmosphere and large quantities of leached tailings, with their high contents of iron, titania and sodium are dumped. The handling of sodium salts is also believed to be environmentally dangerous. The vanadium pentoxide producers in Europe are located in densely populated industrial centres and are thus subject to increasing pressure from environmentalists. It has been speculated by certain industrial specialists (Jacobs, 1991: *Pers Comm*) that environmental factors may be a major factor in the relocation of these facilities in less developed countries where the environmental legislation is more lenient.

5.17 TAXATION

The corporate tax rate is 48% of profits while the current depreciation system is 20% straight line for plant and equipment and 5% for buildings (Financial Mail, 21 June 1991:33). No capital escalation allowance is granted.

The new Taxation Law Amendment Bill, however, proposes that deductions for depreciation and finance charges incurred on new and used plant machinery and property, acquired for beneficiation purposes, be granted in the tax year in which expenditure was incurred. The Bill proposes that a committee, appointed by the Finance and Trade and Industry Ministers, must approve all claims.

To qualify for the new assistance measures, companies will have to give assurances that the capital g: ıds for which they are claiming will be used for added value, and will be commissioned within a period determined by the committee Secondly, the company must prove that the process adds substantial value and that beneficiation would be feasible. Lastly, the company must export at least 60% of the beneficiation product.

The Taxation Laws Amendment Bill was implemented on 30 September 1991.

5.18 GOVERNMENTAL INCENTIVES

By the end of 1992 the power rebate system will come to an end. Ferroalloy producers will, however, still enjoy benefits derived from the export incentive system which came into operation on 1 April 1990. The Export Marketing Assistance Scheme is designed to assist South African exporters to make contact with foreign buyers with a view to concluding export orders. Secondly, exporters may derive benefits stemming from the general export incentive scheme (GEIS).

The value of this incentive is calculated by means of a formula as shown below:

$$Z = V \times (M + \text{or} - E) \times P$$

where	Z	=	The assistance provided to the exporter in respect of exports to a value V.
	V	=	Export sales value, determined by the FOB value
	M	=	Manufacturing level factor
	E	=	Exchange rate factor through which M is adjusted for inflation and exchange rate fluctuations. The E value is - 6%
	P	=	Local content factor

The degree of processing to which a product has been subjected, will determine what M value will be awarded in respect of a particular export. Ferrovanadium is classified as a beneficiated primary product (Swiegers, 1991: *Pers Comm*) and thus is assigned a value of 0,075.

The calculation of factor P is made by using the formula

$$P=\frac{V-I}{V}$$

where V = Export sales value

I = Value of imputs known to be imported

If P is 75% or more the factor is 1

Based on these determinants it is calculated that assistance in the order of 1,5% of the FOB value is provided to the ferrovanadium exporter.

The erratic nature of government incentives rules them out as a determining factor in the feasibility of this project. Feasibility studies concentrate on economic factors such as product costs and revenue estimation. The assistance afforded to the ferrovanadium exporter is thus not included in the discounted cash flow analysis. The project must prove to be feasible without these incentatives. If government assistance is received, it will be regarded as an extra bonus.

5.19 PROTECTIVE TARIFFS

The major markets for vanadium bearing minerals are duty protected. The protective tariffs applicable to the various vanadium products are shown in Table 5.9.

Table 5.9 Protective tariffs applicable to the various vanadium products

	EEC	USA	JAPAN
Slag	0	0	0
V_2O_5	5,6% adval	16% adval	0
FeV (80% V)	9,0% adval	16% adval	8% adval

Note: In 1990 however the EEC voted in favour of a duty free quota for 3150 tons of vanadium pentoxide.

It is evident from the table that the effective tariffs on the processing value added is fairly high. Slag can enter the USA, Europe and Japan duty free, whilst the protective tariffs on ferrovanadium ranges from 8% to 16%.

Highveld Steel and Vanadium recently announced that it would commission a modification at the Vantra division which would allow it to convert up to 20% of its vanadium slag output to vanadium pentoxide. Motivating the beneficiation plan was a reduction from 12% to 5,6% of import duty barriers applied to vanadium pentoxide by the EEC, and the implementation of a duty free quota for 3150 tons.

It is speculated that overseas converters, who are under cost and environmental pressures, will participate in this venture. The preceding example serves to highlight how the protective tariffs abroad are hindering the local beneficiation of vanadium ores.

Dr A Edwards, President of Mintek, believes the problem of protective tariffs could be alleviated if local mineral producers set up joint beneficiation ventures with overseas partners. He sites the example of Highveld Steel and Vanadium forming a consortium of major companies. In such cases the overseas partners would lobby for these duties to be relieved. Although this argument is plausible, it is felt that it will not be applicable to a small player in the market.

It is thus concluded that the existence of protective tariffs, greatly hinders local beneficiation of ferrovanadium.

5. 20 FINANCIAL APPRAISAL OF THE PROJECT.

5.20.1 Modelling Assumptions

The data used for the financial appraisal of this project is for a ferrovanadium plant located in the Witwatersrand, based on 1991 statistics. For simplicity sake it is assumed that the total output is destined for the European market. Certain key assumptions have been made in the financial model and they may be summarized as follows:

(i) Based on a rand/US dollar exchange rate of 2,85 for 1991, the price of ferrovanadium is R40,47 per kg. For the first five years of production, a discount in the order of 10% will be offered.

(ii) Vanadium pentoxide costs account for approximately for 76% of production costs. Taking into account the 5% ¨scount, vanadium pentoxide costs are R26 741 per kg ton of ferrovanadium.

(iii) Scrap alumininium, which accounts for 7,9% of production costs, amounts to R2696 per ton of ferrovanadium.

(iv) Other raw material costs, which include burnt lime and fine iron scrap, are R126 per ton of ferrovanadium.

(v) Electricity costs, reflecting power consumption of 800 kwh per ton of ferrovanadium are R73,04 per ton of ferrovanadium.

(vi) Transport costs from plant to any major European port are R598,43 per ton of ferrovanadium.

(vii) Salaries and wages amount to approximately R1 533 per ton of ferrovanadium.

(viii) Marketing costs account for 4% of total revenue.

(ix) Other costs, including packaging amounts to R300 per ton of ferrovanadium.

(x) The protective tariff payable in the European Economic Community is a 9% advalorem duty.

(xi) Taxation is at 48% of profits while the capital redemption period is one year.

(xii) Initial capital required for plant constru R5,5 million, whereafter maintenance costs will amount to [illegible] million per annum.

(xiii) The preproduction period is one year. In the first year of commisioning production is 750 tons, and then 1500 tons for the remainder of the lifespan of the project. The design capacity of the plant is 3000 tons per annum.

(xiv) The Rand ferrovanadium price is escalated annually at the forecast inflation rate. In dollar terms the ferrovanadium price will only escalate by 4%, however, the Rand is expected to devalue against the Dollar by approximately 12% per annum.

(xv) Operating costs are escalated annually at the forecast domestic rate of inflation, which is taken to be 16% per annum. Capital expenditure is assumed to escalate at 20% per annum.

(xvi) The discount rate for calculating net present values is usually related to the banks' prime overdraft rate, or the rate at which the cash would be invested in the money market, or the rate at which it could be expected to earn if invested in alternative projects of equal risk. Real rates of return for new projects normally range from 5% to around 15% depending on the nature of the project.

For example, Rhombus Vanadium Holdings Limited used an 8% real discount rate, over a 25 year period to evaluate the feasibility of establishing its vanadiferous magnetite mine (Rhovan Listing Statement; 1989:26). Based on a personal perception of the riskiness of this project a real discount rate will be used.

(xvii) Every mining venture and mineral beneficiation venture has to be financed in some way. The finance can be supplied from various sources, with varying terms and conditions to satisfy the needs of the particular investor and the risk/return relationship required.

The way in which financing is arranged is the capital structure and this is a matter of policy. Management must decide on the level of debt, relative to equity, that it wants to maintain. Within the debt and within the equity it can decide on the types of debts and the types of equity that it plans to hold. The decisions are influenced by the policy or the strategy the management decides on. The policy in turn is influenced by the risk profile management chooses to adopt.

In making the decision between raising finance through debt or through equity, there always exists a trade off between risk and return. The implications in choosing between debt or equity financing focuses around:

(i) return: debt is cheaper than equity
(ii) risk: debt is riskier than equity
(iii) control: debt has less impact on the control of a company than eq

For the purpose of this project, a debt to equity ratio of 40:60 will be chosen. The finance to be arranged must cover the capital cost requirements and the working capital elements. Working capital is assumed to amount to 25% of direct working costs. In total, approximately R11,5 million needs to be raised.

Initial capital required for plant construction is R5.5 million and the remainder of the sum is attributed to working capital requirements. It is assumed that a long-term loan of R5 million at an interest rate of 18% will be raised in year one and will be repaid in year ten.

5.20.2 Decision Making Criteria Results

Current practice in economic evaluation combines a list of criteria for decision making with sensitivity and simulation analysis to provide a basis for economic evaluation of investment alternatives.

The fundamental underlying all quantitative techniques is ... mise the net present value of the firm. The net present value me... ...es into account the time value of money. It consists of estimating a project's future cashflows, discounting these cashflows at the company's required rate of return and subtracting from the present value the cost of the investment. Variations of this central theme include maximisation of the internal rate of return. The internal rate of return is the discount rate which causes the present value of the future cash flows to be equated to the cost of the investment. Other criteria may be used to reinforce the conclusions stemming from these decision making criteria.

Based on the preceding assumptions, the cash flows acruing to the project over a 20 year period are summarised in Table 5.10. In Table 5.11 the net present value of the project at various discounting rates is shown.

Table 5.10 Cash Flows Accruing to the Project over a 20-year Period
Tax + lease = .48 x profit - 0 x revenue

Year	Revenue	Working Costs	Capital Expenditure	Net Profit	Loss Bt Forward	Loss Car Forward
1	0.00E+00	0.000E+00	66.00E-01	-6.600E+00	[illegible].00E+00	6.60E+00
2	3.68E+01	3.869E+01	72.00E-02	-3.551E+00	6.60E+00	1.02E+01
3	8.63E+01	8.618E+01	86.40E-02	-2.669E+00	1.02E+01	1.28E+01
4	9.89E+01	9.997E+01	10.37E-01	-2.987E+00	1.28E+01	1.58E+01
5	1.15E+02	1.160E+02	12.44E-01	-3.362E+00	1.58E+01	1.92E+01
6	1.33E+02	1.345E+02	14.93E-01	-3.800E+00	1.92E+01	2.30E+01
7	1.72E+02	1.583E+02	17.92E-01	1.062E+01	2.30E+01	1.24E+01
8	1.99E+02	1.836E+02	21.50E-01	1.239E+01	1.24E+01	0.00E+00
9	2.31E+02	2.130E+02	25.80E-01	1.443E+01	0.00E+00	0.00E+00
10	2.68E+02	2.470E+02	30.96E-01	1.678E+01	0.00E+00	0.00E+00
11	3.11E+02	2.866E+02	37.15E-01	2.039E+01	0.00E+00	0.00E+00
12	3.60E+02	3.324E+02	44.58E-01	2.350E+01	[illegible]E+00	0.00E+00
13	4.18E+02	3.856E+02	53.50E-01	2.708E+01	0.00E+00	0.00E+00
14	4.85E+02	4.473E+02	64.20E-01	3.120E+01	0.00E+00	0.00E+00
15	5.63E+02	5.189E+02	77.04E-01	3.594E+01	0.00E+00	0.00E+00
16	6.53E+02	6.019E+02	92.44E-01	4.138E+01	0.00E+00	0.00E+00
17	7.57E+02	6.982E+02	11.09E+00	4.763E+01	0.00E+00	0.00E+00
18	8.78E+02	8.099E+02	13.31E+00	5.481E+01	0.00E+00	0.00E+00
19	1.02E+03	9.395E+02	15.97E+00	6.304E+01	0.00E+00	0.00E+00
20	1.18E+03	1.090E+03	19.17E+00	7.249E+01	0.00E+00	0.00E+00

Table 5.10 (Continued)

Year	Taxable Profit	TAX + LEASE	Net Cash Flow Current	Net Cash Flow Real
1	[illegible]E+00	0.00E+00	-1.600E+00	-1.379E+00
2	0.[illegible]E+00	0.00E+00	-3.551E+00	-2.659E+00
3	0.00E+00	0.00E+00	-2.669E+00	-1,1710E+00
4	0.00E+00	0.00E+00	-2.987E+00	-1.650E+00
5	0.00E+00	0.00E+00	-3.362E+00	-1.601E+00
6	0.00E+00	0.00E+00	-3.806E+00	-1.562E+00
7	0.00E+00	0.00E+00	-1.062E+01	3.758E+00
8	3.566E-02	1.712E-02	1.237E+01	3.774E+00
9	1.443E+01	6.927E+00	7.506E+00	1.973E+00
10	1.678E+01	8.055E+00	3.727E+00	8.448E-01
11	2.[illegible]9E+01	9.786E+00	1.060E+01	2.072E+00
12	2.350E+01	1.123E+01	1.222E+01	2.059E+00
13	2.708E+01	1.300E+01	1.408E+01	2.045E+00
14	3.120E+01	1.498E+01	[illegible]22E+01	2.031E+00
15	3.594E+01	1.725E+01	1.869E+01	2.017E+00
16	4.138E+01	1.986E+01	2.152E+01	2.002E+00
17	4.763E+01	2.286E+01	2.477E+01	1.987E+00
18	5.481E+01	2.631E+01	2.850E+01	1.971E+00
19	6.304E+01	3.026E+01	3.278E+01	1.954E+00
20	7.249E+01	3.480E_01	3.770E+01	1.937E+00

Table 5.11 Net present values at various discounting rates

REAL TERMS DISCOUNT RATE P.A.	PV INVESTMENT	PV RETURNS	NET PV
-400.000E-02	-121.345E-01	523.122E-01	401.777E-01
0.000E+00	-105.411E-01	304.241E-01	198.830E-01
300.000E-02	-95[illegible]51E-02	209.404E-01	113.939E-01
400.000E-02	-924.694E-02	185.963E-01	934.940E-02
600.000E-02	-868.995E-02	147.862E-01	609.630E-02
700.000E-02	-843.085E-02	132.363E-01	480.550E-02
800.000E-02	-818.366E-02	118.784E-01	369.476E-02
100.000E-01	-772.225E-02	963.445E-02	191.220E-02
120.000E-01	-730.071E-02	788.444E-02	583.730E-03
160.000E-01	-656.029E-02	540.979E-02	-115.050E-02
200.000E-01	-593.375E-02	381.891E-02	-211.484E-02
300.000E-01	-473.329E-02	176.553E-02	-296.776E-02
400.000E-01	-388.939E-02	907.334E-03	-298.205E-02
500.000E-01	-327.292E-02	502.933E-03	-275.998E-02

IRR = 13.10547 p.a.

It is evident from Table 5.11 that at a discount rate of 10%, the net present value is R1,9 122 million. The real internal rate of return is 13,11% per annum. It may thus be concluded that when a minimum "hurdle" rate of 12% is used the project is feasible under the base case scenario.

The results of the other decision making criteria are shown in Table 5.12.

Table 5.12 Other decision Making Criteria

P.V. of outflows	7,30 million
P.V. of inflows	7,88 million
P.V. ratio at 12%	1,08
Potential capital appreciation or benefit-cost ratio	7,95%
Discounted Payback Period	17,4 years
External Rate of Return using 8% reinvestment rate	10,66%

The present value ratio is defined as the ratio of the present value of inflows over the present value of outflows. If the present value ratio is greater than 1, then the proposal is accepted. The present value ratio at 12% is 1,08. This criteria thus reinforces the belief that this project is feasible.

The payback method measures the time it takes for a firm to recover the cost of the investment from the cash flows generated by the project. It is often used as a crude indicator of risk as it indicates how long the funds are at risk. The discounted payback method works on the same concept, however, it takes into account the time value of money. The discounted payback period is 17,4 years, indicating a relatively high level of risk.

The external rate of return criteria distinguishes btween the rate for the "cost of capital" and for reinvestments of the positive cashflows.

This method thus overcomes one of the major drawbacks of both the net present value and internal rate of return, namely that a single discount rate is determined which must hold over a relatively long period into the future. The reinvestment rate is assumed to be 8%. Based on this assumption the external rate of return is 10,66%. When evaluating this project, using this decision making criteria the project is considered to be unviable. It must be noted that this criteria is highly dependent on the assumption of the reinvestment rate. The reinvestment rate is usually less easy to assess than for the cost of capital to the firm.

5.20.3 **Sensitivity Analysis**

A project's net present value is based on best estimates for a number of different variables such as annual operating revenues, annual operating costs and capital expenditure costs. Sensitivity analysis measures how a project's internal rate of return changes, if we change the value of any input variable. We assume that all other variables stay constant.

The change in the internal rate of return can be plotted against the change in the value of a variable. The possible rate of return values are set on the vertical axis, whilst the horizontal axis measures percentage deviations from the expected values. The slope of each line measures how sensitive a project's internal rate of return value is to changes in an input variable. The slope of the line is determined by the method of least squares, which requires that the line fitted to the data be such that the sum of the squares of the verical deviations of the points from the line is a minimum.

Tables 5.13 and 5.14 and Figures 5.12 and 5.13 reflect the results of a sensitivity analysis for this ferrovanadium project over a 20 year life span.

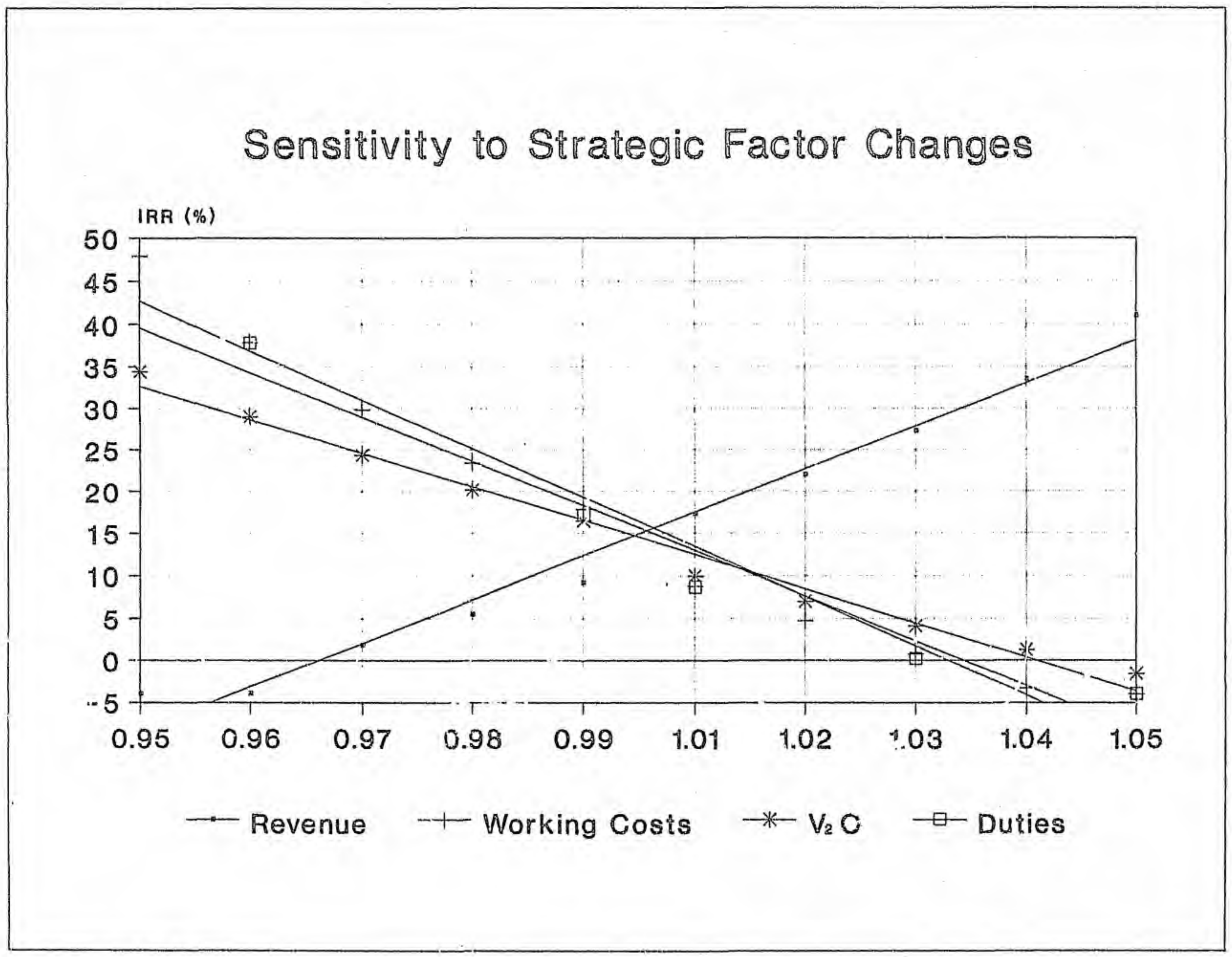
Table 5.13 (IRR)% Sensitivity To Strategic Factor Changes

% CHANGE	REVENUE	WORKING COSTS	V_2O_5	DUTIES
+5	40,98	-4	-1,61	-<-4
+4	33,46	-3,3	1,27	
+3	27,27	0,77	4,11	0,16
+2	21,99	4,72	6,99	
+1	17,26	8,76	9,93	8,63
-1	9,18	17,84	16,44	17,95
-2	5,48	23,42	20,17	
-3	1,82	29,85	24,36	
-4	-3,97	37,87	28,99	37,77
-5	-<4	47,89	34,41	

Table 5.14 IRR(%) Sensitivity To Strategic Factor Changes

% CHANGE	TRANSPORT	MARKET COSTS	CAPEX	AL_2O_3	LABOUR	INFLATION ESCALATION
+50	9,56	4,38	7,25	-1,73	4,05	12,37
+25	11,29	8,62	9,8	5,47	8,34	12,75
+15	12,00	10,36	11,00	8,40	10,15	12,90
+10	12,37	11,25	11,66	9,91	11,10	12,96
+5	12,73	12,17	12,36	11,47	12,09	13,04
-5	13,46	14,02	13,89	14,74	14,12	13,15
-10	13,82	14,96	14,73	16,46	15,17	13,19
-15	14,19	15,92	15,65	18,29	16,27	13,23
-25	14,93	17,93	17,80	22,31	18,61	13,29
-50	16,54	23,54	26,99	34,65	25,63	13,38

From the above analysis, it is evident that ferrovanadium prices and production costs are the major determining factors of the project's financial feasibility. It must be noted that the expense of duties is included in the heading of working costs in Table 5.13. Many industry specialists in the South African ferrous metal beneficiation indusrty believe that the most important consideration in planning new projects is the projected market conditions for the saleable product. (Von Below, 1991:13). The results of this analysis reinforces this belief. The success of this project is highly sensitive to the ferrovanadium price received. For example, a 5% increase in revenue earned. improves the IRR from the most likely base case IRR of 13,11% to 40,98%.



Sensitivity to Strategic Factor Changes
IRR (%)
50
45
40
35
30
25
20
15
10
5
0
-5
0.95
0.96
0.97
0.98
0.99
1.01
1.02
1.03
1.04
1.05
Revenue
Working Costs
V₂ C
Duties

Figure 5.12

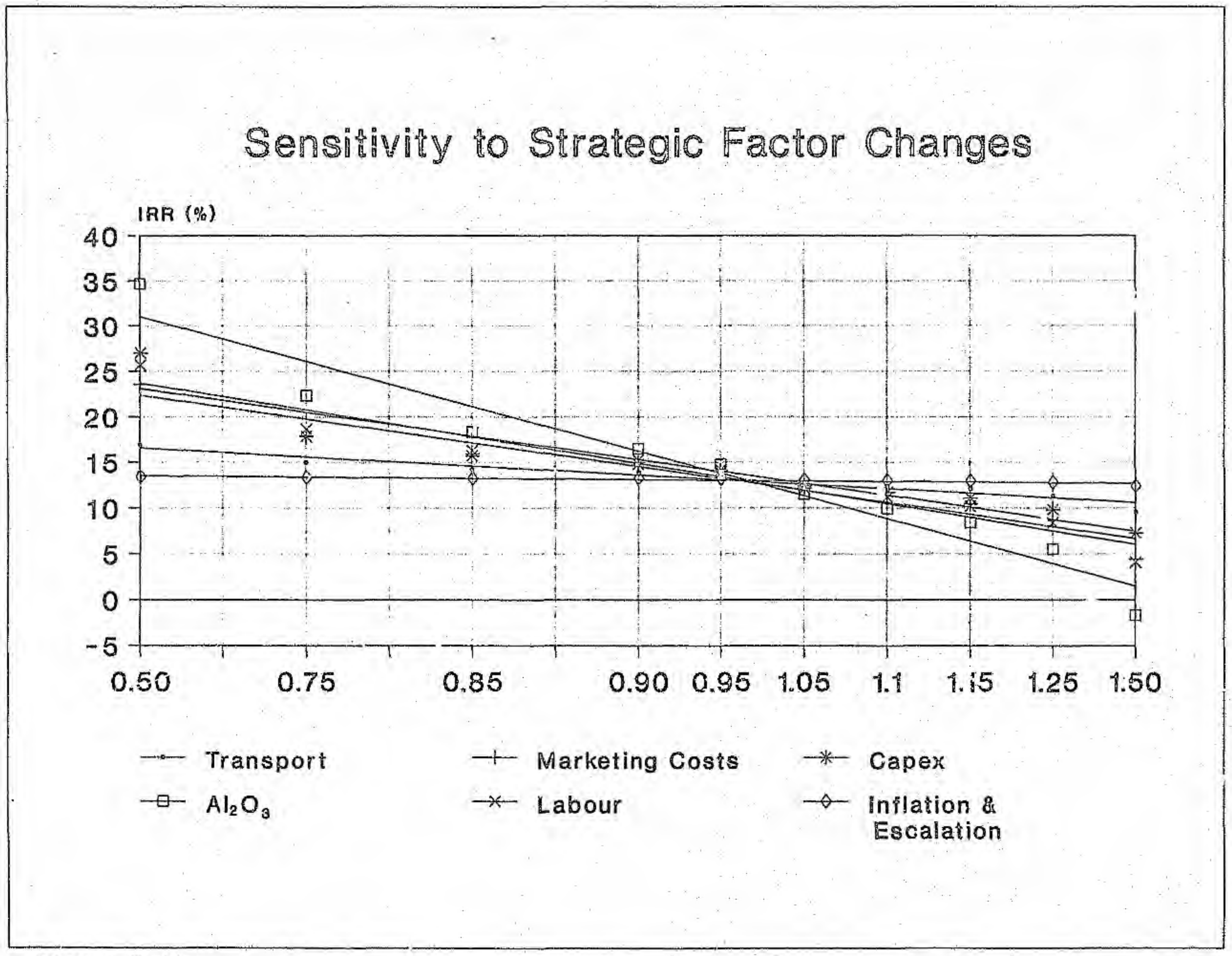

Sensitivity to Strategic Factor Changes
IRR (%)
40
35
30
25
20
15
10
5
0
-5
0.50
0.75
0.85
0.90
0.95
1.05
1.1
1.15
1.25
1.50
Transport
Marketing Costs
Capex
Al2O3
Labour
Inflation & Escalation

Figure 5.13

A change in pricing policy of the company also has a marked effect on the feasibility of this project. Beneficiation projects in South Africa are usually promoted on the basis of raw material and power costs advantages and markets are subsequently found for the product through offering competitive prices. In the most likely case a discount of 10% was offerd for a period of five years. If no discount is offered at all the IRR increases to 95,14%. If, however, the discount period was extended to 10 years the IRR would deteriorate to 1,48%.

If a discount of 5% is offered for a period of five years the IRR increases to 33,65%. The magnitude and the duration of the discount is highly dependent on the actions of the company's major competitors. For example, the duration of the discount may be extended, if the discount is matched by existing producers.

The major components of production costs are the vanadium pentoxide costs, the import duties charged on the final product and the aliminium scrap costs.

Approximately 76% of the cost of ferrovanadium is related to vanadium pentoxide costs. It is thus concluded that in addition to the procurement of a supply contract, the attainment of a favourable vanadium pentoxide price is crucial to the viability of this project. In the base case it was assumed that a discount of 5% could be negotiated with the suppliers. If only the transport cost savings, which amounts to approximately 2,5% of the listed price, are passed on to the ferrovanadium producer the IRR is reduced to 5,55%. If no cost advantages are passed on to the domestic consumer of vanadium pentoxide a negative IRR of -1,61% is achieved.

The import duties charged on ferrovanadium greatly influences the viability of this project. In the base case it was assumed that a 9% duty would be renderd on the final product. This is the effective tarriff paid in the E.E.C. If the product was sold in the U.S.A. a duty of 16% would be paid. The increment of 8% reduces the IRR from the most likely base case IRR of 13,11% to less than -4%.

Based on this result it would not be feasible to export the total output to the U.S.A. If approximately 75% of output is destined for the E.E.C. and the remainder to the U.S.A. market an IRR of 5,45% will be achieved. If these duties were somehow relinquished, the base case IRR would increase by approximately 7 fold. It is thus concluded that a major factor inhibiting the domestic beneficiation of ferrovanadium is the existence of protective tarrifs on this product.

In comparison to these three strategic factors the feasiblity of this project is relatively unresponsive to changes in the remaining strategic elements of this project. For example, if aluminium costs rose by 25%, the internal rate of return would only decrease to 5,47%. Aluminium input costs accounts for approximately 7.6% of production costs.

In the preceding analysis the change in the project's internal rate of return was measured when one input variable was changed while holding all others constant. It is unlikely, however, that an increase in the price of vanadium pentoxide costs would occur in isolation. Normally an increase in the vanadium pentoxide price is reflected in a subsequent increase in the price of ferrovanadium. For example, an increase in the price of vanadium pentoxide by US 10c/1b warrants a US 35c/kg increase in the price of ferrovanadium. The results of a sensitivity study of vanadium pentoxide costs and related ferrovanadium price movements is shown in Table 5.15.

Table 5.15 Vanadium pentoxide sensitivity with related ferrovanadium price movements

% change	IRR%
+3,75	9,05
+7,5	11
+11,27	7,26
+15	5,53
-3,75	17,81
-7,5	22,09

It is clearly illustrated that vanadium pentoxide cost changes, with subsequent ferrovanadium price movements has remarkably less impact on the IRR in comparison with absolute changes in vanadium pentoxide costs. Although the price movements of vanadium pentoxide is reflected in subsequent price changes in ferrovanadium, the IRR decreases as the price of vanadium pentoxide costs rises. This arises due to the discount policy adopted by the company.

It is proposed that the results of the sensitivity analysis on absolute vanadium pentoxide cost changes, should be utilised when assessing the supply contract negotiated with the domestic suppliers of vanadium pentoxide. The latter sensitivity analysis with the related ferrovanadium price movements should in turn be utilised when assessing the effects of raw material input costs during the life of the project.

5.20.4 Risk Analysis

The main objective of risk analysis is to provide management with a simulation, as realistic as possible, of what could happen if the project is undertaken. In other words, it can provide an overall assessment of the chances of success as opposed to the risk of failure.

For the purpose of a risk analysis, the uncertainties for each variable has to be defined in the form of a probability distribution. This is normally done by estimating, subjectively, the likely level at a 90% confidence limit for each variable. The confidence levels are defined as follows.

(i)	Revenue	-30% + 30%
(ii)	Working Costs	-30% + 30%
(iii)	Capital Costs	-20% + 30%
(iv)	Infation and Escalation Rates	-35% + 35%

Having established the probability distributions for the risk variables a complte cash flow is calculated based on the set of selected values and the various criteria for returns are determined. A second set of values for the risk variables is selected and the procedure is repeated. This operation is repeated 100 times, which in turn gives 100 estimates for the DCF criterion.

5.20.4.1 Risk Analysis Results

The results of the risk analysis is illustrated in Table 5.16.

Table 5.16 Risk Analysis Results

IRR	%
<-4	36
-4<IRR<12	7
12<IRR<50	6
>50	51

From these results it is interpreted that the project has a 57% chance ~ achieving a minimum internal rate of return of 12% or even better. The project appears to be a high risk investment as there is a 36% chance of achieving an internal rate of return of less than -4%, whilst on the other hand, there is a 51% chance of achieving an internal rate of return of greater than 50%. The risk analysis undertaken does not take into account the correlation levels between variables eg, the price of ferrovanadium is explicitly related to the price of vanadium pentoxide. It is thus postiulated that the wide disparity between the internal rate of returns arises from this weakness. This factor must thus be considered when interpreting the results of the risk analysis. It is concluded that even if this factor is taken into account, the project's viability is highly uncertain.

In the conventional sensitivity analysis, one risk variable is set at different levels while all the other risk variables are fixed. Where a full risk analysis has been executed, a more meaningful sensitivity analysis can be obtained. On this basis the sensitivity of any one of the investment criteria to variations in any one of the input risk variables can be obtained while all the other uncertain input variables are not fixed but vary according to their probablity disrtibutions as defined. Unfortunately, because of the large disparity of the internal rates of return, such sensitivity graphs can not be plotted.

Based on the results of the financial modelling it is concluded that the project is too risky to justify an in stment of approximately R11,5 million. A substantial part of this risk arises from the inability of the non intergrated firm to control the supply and price of vanadium pentoxide. The procurement of a supply contract at affordable prices is deemed to be the most important factor influencing the feasibility of this project. It is concluded that the project would be viable, however, if the beneficiation is conducted by a firm vertically intergrated into the raw material supplying activity. The structure of the supply contract could be designed such that it would mitigate the normal risks associated with such a venture.

It is recommended that a company such as Highveld Steel and Vanadium should develop a large scale ferrovanadium beneficiating

in the position to exploit this lucrative opportunity as ld's largest producer of vanadium pentoxide. Such a decision would not only bolster the company's perfomance and increase South Africa's export earnings but it would also allow Highveld to exercise greater control over the vanadium market. The South African vanadium indusrty is trying to restore the image of vanadium as a stably priced microalloy readily available from reliable sources, in order to increase vanadium consumption. It is unlikely that price stability can be achieved by control of vanadium pentoxide and slag prices alone, while trader and market forces are dictating the price of ferrovanadium.

One of the major factors prohibiting the domestic beneficiating of ferrovanadium is that its markets are duty protected. Dr. A. Edwards is f the opinion that local mineral producers should set up a joint venture beneficiation project with overseas partn s in order to avoid import duty barriers (Engineering Week, 23 November 1990:12).

The overseas vanadium producers are under cost and environmental pressures and it is anticipated that with the breakdown of apartheid and sanctions these companies will participate in joint beneficiation venture. In such cases the overseas partner would not want import duties to be imposed. In addition to the removal of import duties, the other benefits of a joint venture include the sharing of financial risks and the "capturing" of the overseas partner's markets.

CHAPTER 6

RESEARCH FINDINGS AND RECOMMENDATIONS

The primary objective of this research has been to evaluate the economic viability of beneficiating vanadium pentoxide to ferrovanadium in South Africa. A financial modelling methodology was used to assess the viability of this project. It is assumed that a non-intergrated firm wishes to establish a greenfield ferrovanadium facility producing approximately 7,5% of the world market. Vanadium pentoxide is used as the starting feedstock in the production of ferrovanadium. The major findings of this research are summarised below:

(i) Ferrovanadium is most commonly produced in an electric-arc furnace charged with vanadium pentoxide, aluminium scrap, iron or steel scrap and a flux such as burnt lime. The production technology is relatively simple in comparison to that for vanadium pentoxide. No serious technical commisioning problems are thus envisaged.

(ii) It is believed that in the next few years that the vanadium market will be plagued by oversupply, unfavourable market perceptions and very low prices. In these circumstances a new producer will have to have low production costs in order to justify proceding with such a project. Low production costs will thus be the key to success in the ferrovanadium market.

(iii) The industrial environment in which the South African mineral beneficiation industry operates is unfavourable because of the high cost of capital compared with that of other countries. In contrast to the large capital costs associated with a greenfield vanadium pentoxide plant, the capital expenditure required for a ferrovanadium plant is relatively low. It is thus concluded that the price of capital and capital availability is not a determining factor in the feasibility of ferrovanadium beneficiation.

(iv) Vanadium pentoxide costs are the major input cost used in the production of ferrovanadium. Approximately 1,6 tons of vanadium pentoxide is consumed in the production of a ton of ferrovanadium.

There are five major producers of vanadium pentoxide in South Africa: Highveld Steel and Vanadium, Transvaal Alloys, Vametco, Usko and Vanadium Technology. Highveld is the dominant producer controlling about 70% of South Africa's Vanadium pentoxide capacity. Transvaal Alloys, a subsidiary of Norddeutsche Affinerie of Hamburg, and Vametco - both produce specialised products for niche markets in addition to vanadium pentoxide. Vatmetco is a subsidiary of the US Stratcor group. Usko has a capacity to produce 9000 tons of vanadium pentoxide a year. Unfortunately, it has suffered prolonged commissioning problems. It is speculated that Highveld is on the verge of buying this operation. Vanadium Technology, in co-operation with ore trader Marc Rich, recently purchased Rand Mine's Vansa Vanadium operation. Production is planned to restart early in 1992.

(v) It is proposed that the major determining factor in the feasiblitty of this project is the procurement of a supply contract with a major domestic supplier. It is unlikely that Highveld would supply vanadium pentoxide to a domestic processor who would be in direct competition for the domestic ferrovanadium market, and who would compete against its traditional customers abroad. It is also unlikely that Vametco and Transvaal Alloys would be willing to enter into a supply contract as these are vertically integrated firms with commited output. It is also highly likely that Vanadium Technology assisted by Mark Rich has negotiated a long term contract with a major end-user. For the purpose of this report it is assumed that Vanadium Tecnology would be willing to supply vanadium pentoxide to the domestic ferrovanadium producer.

(vi) The superior nature of local vanadium ore deposits affords the local industry a decisive competitive edge only when beneficiation is conducted by a firm vertically integrated into the raw material supplying activity. Where the beneficiating firm has to purchase its raw material from another party it normally pays a competitive market price. It is concluded that the non-intergrated beneficiation firm will still enjoy a competitive avdantage from purchasing domestically supplied raw materials due to transport cost savings and stonger marketing links with the suppliers. These relatively low vanadium pentoxide costs will thus provide the platform for entry into the ferrovanadium market. It must be noted that the use of cheap vanadium slag as a starting feedstock gives certain ferrovanadium producers a competitive edge over those who buy vanadium pentoxide.

The domestic ferrovanadium producer has thus only a competitive advantage over those ferrovanadium producers who use vanadium pentoxide as a starting feedstock.

(vii) The major input cost into ferrovanadium production after vanadium pentoxide is aluminium. Usually ferrovanadium producers use aluminium scrap, in the form of shredded used beverage cans. It is contended that the availability of cheap sources of aluminium scrap affords the ferrovanadium producer a competitive advantage in the international market. Unfortunately aluminium scrap is not favourably priced in South Africa, and thus domestic ferrovanadium producers are placed at a competitive disadvantage. The local ferrovanadium producer has the option, however, of importing aluminium scrap. If this option is taken the domestic ferrovanadium producer now only pays an effective premium of 10% in relation to the almost 50% permium that would be paid if the aluminium scrap was locally sourced. It must be noted that the feasibility of importing aluminium scrap is dependent on the prevailing exchange rate and the international market price for aluminium.

(viii) The domestic ferrovanadium producer will be competitive in the major cost areas - raw materials, labour, electricity and environmental costs.

(ix) The major ferrovanadium markets are duty protected. The existence of these protective tariffs greatly impedes the local beneficiation of ferrovanadium.

(x) A financial analysis, using a base case scenario, indicates that the project is viable and will yield an acceptable rate of return to shareholders. An examination of a suite sensitivity cases, however, demonstrates that the rate of return is highly volatile. Small changes in the market price, vanadium pentoxide costs, and duties levied have a marked effect on the viability of this project. The results of a risk anlysis serves to show that there is a 43% chance that the project will fail to meet the desired acceptable rate of return.

(xi) Based on the results of the financial modelling it is concluded that the domestic beneficiation of ferrovanadium will only be viable if undertaken by a firm vertically integrated into the raw material supplying activity. The structure of the supply contract could be designed such that it would mitigate the normal risks associated with such a venture.

(xii) It is recommended that a company such as Highveld should proceed with the development of a large scale ferrovanadium beneficiation plant.

Such a decision would not only bolster the company's perfomance and increase South Africa's export earnings, but it would allow Highveld to gain increase control over this cyclical market.

(xiii) One of the major factors inhibiting the domestic processing of ferrovanadium is that most of its markets are duty protected. Many of the overseas vanadium producers are under cost and environmental pressures. It is thus anticipated that these overseas customers would participate in a joint beneficiation venture. In such a case the overseas partner would not want import duties to be imposed and would lobby for their removal. The relaxation of these import duties would greatly increase the attractiveness of the project. In addition, a joint venture would reduce the risk of the project as the markets of the overseas partner will be captured and the financial risks will be shared amongst the partners.

Long lasting industrial growth will only be possible in South Africa if additional revenue is generated through the beneficiation of our major minerals. This observation obviously does not preclude the need to scrutinize each proposed processing venture on its individual merits. An investigation of the feasibility of beneficiating vanadium pentoxide to ferrovanadium serves to show that this is a most attractive opportunity if undertaken by a vertically integrated firm.

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APPENDIX 1

CODE	DESCRIPTION	QTY UNIT
FILE :	WITSFEV	
1000	CIVILS	
	V_2O_5 BI.	
	A1 BIN	
	BURNT LIME BIN	
	Fe BIN	4 M3
	TRAVELLING SCALE CAR	8 M3
	FURNACE CHAGE BIN	2 M3
	FURNACE SHELL	7 M3
	TAPPING LADLE	2 M3
	TAPPING PLATFORM	4 M3
	CRUSHER FEED TABLE	2 M3
	HAND FED JAW CRUSHER	4 M3
	PICKING BELT	2 M3
	SIZING TROMMEL	2 M3
	ROAD WEIGH BRIDGE	10 M3
	CRANE AISLE	20 M3
	WATER COOLING PLANT	5 M3
	ELECTRICAL EQUIPMENT ROOM	20 M2
	OFFICE, LAB, STORE	
	WORKSHOP & ABLUTIONS	60 M2
	CRANE AISLE CONCRETE AREA	160 M2
	SLAG PIT	10 M3
2000	STRUCTURALS	
	V_2O_5 BIN	2 T
	A1 BIN	1 T
	BURNT LIME BIN	1 T
	Fe BIN	1 T
	FURNACE CHARGE BIN	2 T
	FURNACE GAS DUCT	2 T
	TAPPING PLATFORM	1 T
	CRUSHER FEED TABLE	1 T
	CRANE AISLE	20 T
	ROOFING	290 M2
	SIDE CLADDING	250 M2

CODE	DESCRIPTION	QTY UNIT
3000	MECHANICALS	
	V_2O_5 BIN FEEDER	1
	Al BIN FEEDER	1
	BURNT LIME BIN FEEDER	1
	Fe BIN FEEDER	1
	TRAVELLING SCALE CAR	1
	FURNACE CHARGE BIN FEEDER	1
	FURNACE SHELL	3 T
	FURNACE ROOF	1 T
	FURNACE REFRACTORIES	16 T
	FURNACE ANODE SYSTEM	1
	FURNACE ELECTRODE ASSEMBLY	1
	ELECTRODE BUSBARS	1 SET
	HYDRAULIC STATION	1
	FURNACE GAS FILTER	1
	TAPPING LADLE	5
	TAP PLATFORM, DRILL, ETC	1
	CONTAINERS FOR MATERIAL IN PROCESS	20
	HAND FED JAW CRUSHER	1
	PICKING BELT	8
	SIZING TROMMEL	1
	ROAD WEIGH BRIDGE	1
	O/1 TON OVERHEAD CRANE	1
	WATER COOLING PLANT	1
4000	ELECTRICAL & INSTR.	
	V_2O_5 BIN FEEDER	1 DR
	Al BIN FEEDER	1 DR
	BURNT LIME BIN FEEDER	1 DR
	Fe BIN FEEDER	1 DR
	TRAVELLING SCALE CAR	1
	FURNACE CHARGE BIN FEEDER	1 DR
	FURNACE 2MW POWER SUPPLY	1 SET
	FURNACE INSTR & CONTROL	1 SET
	REFRACTORY THERMOCOUPLES	6
	HYDRAULIC STATION	1
	FURNACE GAS FILTER	1 DR
	HAND FED JAW CRUSHER	1 DR
	PICKING BELT	1 DR
	SIZING TROMMEL	1 DR
	ROAD WEIGH BRIDGE	1
	O/H CRANE HOT RAILS	35 M
	WATER COOLING PLANT	3 DR
	ELECTRICAL EQUIPMENT ROOM	1
	PLANT LIGHTING	1 SET

CODE	DESCRIPTION	QTY UNIT
5000	ERECTION	
	V_2O_5 BIN FEEDER	2 M/DAY
	A1 BIN FEEDER	2 M/DAY
	BURNT LIME BIN FEEDER	2 M/DAY
	Fe BIN FEEDER	2 M/DAY
	TRAVELLING SCALE CAR	7 M/DAY
	FURNACE CHARGE BIN FEEDER	2 M/DAY
	FURNACE SHELL	3 M/DAY
	FURNACE ROOF	2 M/DAY
	FURNACE REFRACTORIES	7 M/DAY
	TAP PLATFORM EQUIPMENT	3 M/DAY
	FURNACE 2MW POWER SUPPLY	10 M/DAY
	FURNACE INTR & CONTROL	30 M/DAY
	REFRACTORY THERMOCOUPLES	2 M/DAY
	FURNACE ANODE SYSTEM	2 M/DAY
	FURNACE ELCTRODE ASSEMBLY	20 M/DAY
	ELECTRODE BUSBARS	7 M/DAY
	HYDRAULIC STATION	5 M/DAY
	FURNACE GAS FILTER	12 M/DAY
	TAP PLATFORM, DRILL ETC	3 M/DAY
	CRUSHER FEED TABLE	2 M/DAY
	HAND FED JAW CRUSHER	3 M/DAY
	PICKING BELT	4 M/DAY
	SIZING TROMMEL	3 M/DAY
	ROAD WEIGH BRIDGE	10 M/DAY
	O/H CRANE HOT RAILS	5 M/DAY
	WATER COOLING PLANT	8 M/DAY
	ELECTRICAL EQUIPMENT ROOM	20 M/DAY
	PLANT LIGHTING	5 M/DAY
7000	ENGINEERING	
	LUMP SUM	1
	OVERHEADS	100 %
8000	CONSULTANTS & ADMINISTRATION	
	LUMP SUM	1
9000	LICENCE FEES	