VENMYN RAND PTY Ltd

REPORT NO. VMR 1a/2009

RIVIERA TUNGSTEN DEPOSIT
METALLURGICAL PLANT

UPDATE: ORDER OF MAGNITUDE PROCESS EVALUATION, CONCEPTUAL SIZING, COST AND LAYOUT FOR 3mtpa AND UPDATED FOR 0.7mtpa

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February 2009

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1. INTRODUCTION

This report follows on from report VMR 5/2008, March 2008, which conducted a high-level review of the Riviera Tungsten project covering,

- Production recoveries, capital and operating costs and
- The adequacy of metallurgical testwork done to date to confirm whether the metal can be extracted from the ore.

Venmyn has been retained by Rock Ventures Pty Ltd to assist in the preparation of a mining right application for their tungsten property held in the Piketberg Magisterial District of the Western Cape Province. Details of the scope of work can be found in Venmyn's letter to Bongani Minerals Pty Ltd of 10th November 2008.

Venmyn requested Eurus Mineral Consultants to supply module 2 of their total scope which includes the following;

- A detailed conceptual plant with estimates of plant efficiency and recoveries,
- Electrical power and water requirements,
- List of major items of equipment,
- Plant mass balance and expected concentrate quality,
- Plant layout and other ancillary infrastructure and
- Capital cost of major items of equipment, cost of construction and operating cost.

Costs are detailed for a throughput of 3.0 mtpa. These costs are ratioed according to the six-tenths rule to determine capital and operating costs for an operation of 0.7 mtpa.

2. SUMMARY

Process

The metallurgical plant is divided into two operations,

- The Concentrator plant, utilising mill, float and gravity operations to generate molybdenum sulphide and tungsten oxide (Scheelite) concentrates and
- A Concentrates Treatment plant to produce ammonium paratungstate (APT) via either a soda ash leach route involving crystallisation or an alkali caustic soda leach route involving either solvent extraction or ion exchange.

The Riviera operation has the option to produce and sell,

- A low grade flotation/gravity concentrate at 30% WO_3,
- A leached flotation/gravity concentrate which would be of usual marketable grade (60-65% WO_3) or
- APT at 96.8% WO_3.

The Concentrator uses bulk standard unit operations in common use in South Africa and therefore attaches a fairly low risk element in terms of the complexity of technology and operation. Complexity and operational risk is low-normal for a metallurgical complex consisting of only a Concentrator and high if the complex includes a concentrates processing plant to produce ammonium paratungstate. Feedback from Dragon Capital Management Ltd whose 70% owned Nui Phao tungsten mining project in Vietnam is in an advanced development stage is that,

- Finding an experienced APT engineering firm is tough, as most of the APT plants built in the 'west' occurred 25+ years ago and
- Western' technology is considered old and superseded now, given the significant advances made by the Chinese (they're the only ones we know who have built any new/recent plants).

Recovery

Due to the ore's mineralogy, upgrading to a marketable grade by flotation and gravity will result in significant recovery loss. To maximise recovery in the Concentrator a float/gravity concentrate of 30% WO_3 at 80% recovery will be acid leached to generate a 60-65% WO_3 product at 76.0% recovery. A separate molybdenum sulphide concentrate will be produced at 52% MoS_2 at 60% recovery. If APT is produced, tungsten recovery is estimated to be 74.5%.

Order of Magnitude Capital and Operating Costs

For a nameplate capacity of 3mtpa + 10% (415t/hr), the total cost of a Concentrator inclusive of infrastructure and tailings dam is R909.5m. The Concentrates Treatment plant (treating 1.2t/hr) is estimated to cost an additional R92m.

Operating cost is estimated as R54.7/t milled for the Concentrator and R82.1/t milled for the combined plants producing APT. Major costs for the Concentrator are consumables (R26.63/t, including water at R2.25/t) and power at R13.74/t.

For the smaller throughput of 0.70mtpa + 10% (96t/hr), the total cost of a Concentrator inclusive of infrastructure and tailings dam is estimated via the six-tenths rule as R380m. The Concentrates Treatment plant (treating 1.2t/hr) is estimated to cost an additional R50m.

Operating cost is estimated as R189/t milled for the Concentrator and R283/t milled for the combined plants producing APT.

Layout of Metallurgical Complex

The metallurgical complex is housed within an area 125m by 325m.

Acquisition and Accuracy of Data

The main data source for the Concentrator was the testwork conducted by Union Carbide in 1981. This was supplemented by information from conference proceedings and the internet. Although not voluminous, concentrator information is readily available. Basic information about the flowsheet and technology for the Concentrates Treatment plant is not publicly available as it is deemed to be proprietary information of members of the International Tungsten Industries Association (ITIA) and the China Tungsten Industry Association (CTIA).

Order of magnitude estimates are usually +/- 40% accuracy. Considering the availability and content of process data, the accuracy of capital and operating costs are defined as -30% + 10% for the Concentrator and -40% + 40% for the Concentrates Treatment plant.

Benchmarking

Riviera ore is benchmarked against other producers and detailed feasibility studies owned by North American Tungsten, Geodex Minerals, Rio Tinto, Adex Mining, Ormonde Mining and Wolf

Minerals (Cantung, Sisson Brook, King Island Scheelite, Mt Pleasant, Barruecopardo and Hemerdon).

Production of Ammonium Paratungstate

The production of APT from flotation concentrate is an additional step. It is a complex process, the details of which are evidently a closely guarded secret. If APT production is an option it is suggested that the client initiates a relationship with a company which is knowledgeable in this regard such as Wardrop Engineering, Canada and/or SGS Lakefield, Canada.

Again, quoting Dragon Capital Management Ltd,

"We're using a small boutique engineering group out of Brisbane (Australia) with links into a Chinese design institute, but we're still at a very early learning stage. In the past we approached Hatch, Aker, and Ausenco, but none of them had any experience and quoted exorbitant pay rates."

3. DATA SOURCES

Data analysed in this report was sourced from;

- Metallurgical Evaluation – Riviera Project, R. G. Woolery, March 16th 1981. Union Carbide Exploration Corporation, Southern Africa,
- Technical Report on the Burnt Hill Tungsten Deposit, Eugene Puritch, March 31st, 2006. (http://www.norontresources.com/projects/burnt-hill/index.html)
- Cantung Tungsten Mine data ex North American Tungsten Corporation Ltd website (http://www.northamericantungsten.com/s/Cantung.asp)
- All other data quoted is in the public domain, either on the internet or in EMC archives,
- F L Smidth Pty Ltd for Concentrator plant budget equipment costs,
- Concentrates Treatment plant equipment costs from Matches (Oklahoma, USA) via their website http://www.matche.com.

4. TERMS OF REFERENCE, NOMENCLATURE AND CONVERSION FACTORS

Resource and treatment rate is 46mt resource at 0.22% WO_3 and 0.020% Mo, treated at 3.0mtpa (250ktpm, 385 t/hr). A second treatment option of 0.70mtpa (58.3ktpm, 90t/hr) at 0.31% WO_3 and 0.020% Mo is also considered.

Venmyn is abbreviated as VMR.

Eurus Mineral Consultants is abbreviated as EMC.

Ammonium Paratungstate is abbreviated as APT.

Metric tonne unit = MTU ($W:WO_3$ = 1.0:1.2616)

NORTH AMERICAN TUNGSTEN CORPORATION LTD

A WORLD CLASS TUNGSTEN COMPANY

Tungsten Conversion Measurements

W (Elemental Tungsten) : 1	WO_3 (Tungsten Concentrate) : 1.2616
1 Short Ton	2,000 lbs
1 Metric Tonne	2,204.6 lbs
1 STU (Short Ton Unit)	20 lbs (1% of a Short Ton)
1.102297 STU	1 MTU (Metric Ton Unit)
1 MTU	10 kgs (1% of a Metric Tonne)
1 MTU	22.04 lbs
1 Ton (2,000)	0.907 Tonnes
1 Tonne	100 MTU

NOTE: If the price of WO_3 is US$265/MTU = US$26.50/kg = US$12.02/lbs

5. COMMENTS ON THE PROCESS FLOWSHEET AND TECHNOLOGY

5.1 Acquisition of Data

The main data source for the Concentrator was the testwork conducted by Union Carbide in 1981. This was supplemented by information from conference proceedings and the internet. Although not voluminous, concentrator information is readily available. A list of references is shown in the Appendix (these have not been accessed and studied as this level of detail is beyond the project scope).

Opposite to this is the concentrates processing plant. Basic information about the flowsheet and technology is not publicly available and a rigorous search of the internet, text books, current producers, other consultants and process engineering companies, members of the International Tungsten Industries Association (ITIA) and members of the China Tungsten Industry Association (CTIA) produced the relatively small amount of information in this report. The response from organisations that have a detailed working knowledge of the APT process is illustrated by the typical reply reproduced below.

From: Jiang Hanns [mailto:sales@chinatungsten.com]
Sent: Thursday, January 08, 2009 11:13 AM
To: martynhay
Subject: Our Ref:C200901080072, About APT

mailto:martynhay@worldonline.co.za

Dear Martyn,

Thanks for your interest in Chinatungten.
However, we could not offer APT processing flowsheet to you, because it is regarded as business secret.
We are sorry we could not help you on this issue, and thanks for your understanding.

With best regards.
Jiang Hanns/GM
Chinatungsten Online (Xiamen) Manu. & Sales Corp.

ADD. 2-27B,Wuhan Building,No.261-265 Jiahe RD,Xiamen SEZ
Fujian 361009 P.R.China
Tel: 0086 592 512 9595,0086 592 512 9696 Fax: 0086 592 512 9797
Email: sales@chinatungsten.com, hanns@chinatungsten.com, sales@chinatungsten.biz, chinatungsten@gmail.com
URL: www.chinatungsten.com, www.tungsten.com.cn

5.2 Production Set-Up

The tungsten industry is considered to comprise three principal divisions:

- **Primary Tungsten Producers** – the mines which mine and carry out primary mineral processing to produce tungsten mineral concentrates,
- **Secondary Tungsten Processors** – the processing plants which take the mineral concentrates and process them into a number of tungsten powders, including ammonium paratungstate (**APT**), suitable for use in downstream metal/alloy manufacturing. These powders are often referred to as "**intermediates**",
- **Tertiary Tungsten Product Manufacturers** – the plants which produce finished tungsten metal, tungsten alloys, tungsten tools and other tungsten end products.

5.3 Metallurgical Plant Set-Up

The metallurgical plant is divided into two sections,

a. The Concentrator, utilising mill, float and gravity operations to generate molybdenum sulphide and tungsten oxide (Scheelite) concentrates and
b. An optional concentrates processing plant to produce ammonium paratungstate (APT) via,
    i. An alkali soda ash leach route involving crystallisation or
    ii. An alkali caustic soda leach route involving either solvent extraction or ion exchange.

The operation can produce and sell;

- A low grade flotation/gravity concentrate,
- A leached flotation/gravity concentrate which would be of usual marketable grade (60-65% WO_3). If it can be generated, pure scheelite concentrate is marketable as it may be added directly to molten steel,
- Ammonium paratungstate.

Complexity and operational risk is low-normal for a metallurgical complex consisting of only a Concentrator and high if the complex includes a concentrates processing plant to produce ammonium paratungstate. Feedback from Dragon Capital Management Ltd whose 70% owned Nui Phao tungsten mining project in Vietnam is in an advanced development stage is that,

- Finding an experienced APT engineering firm is tough, as most of the APT plants built in the 'west' occurred 25+ years ago and

- Western' technology is considered old and superseded now, given the significant advances made by the Chinese (they're the only ones we know who have built any new/recent plants).

5.4 Concentrator producing Molybdenum and Tungsten Concentrates

The Concentrator uses bulk standard unit operations in common use in South Africa and therefore attaches a fairly low risk element in terms of the complexity of technology and operation. A process flowsheet, mass balance and major equipment sizing was generated from a combination of testwork results generated by Union Carbide in 1981, industry experience and benchmarking metrics relevant to the various unit processes.

The Riviera orebody consists almost entirely of scheelite ($CaWO_4$) which is a friable mineral and therefore liberates quite readily at 250-300µm, thus only coarse milling is required to 80% -200µm or 45% -75µm. Scheelite is more friable than Wolframite and tends to naturally slime. Tests showed that 12.9% WO_3 concentrated in the -37µm fraction in 10.3% by mass, and 27.9% WO_3 in the -37µm fraction in 21.2%% by mass. Since scheelite is non-magnetic its recovery circuit excludes magnetic separation. Although not specifically tested, gravity concentration will probably be required to treat flotation tailings to scavenge any remaining Scheelite and Wolframite ($(Fe,Mn)WO_4$). The scheelite is often finely disseminated in the orebody and therefore suffers high recovery loss when attempting to produce a marketable concentrate grade of +65% WO_3. Recovery is best maximised by producing a lower grade of final concentrate and leaching this to produce the required marketable grade. This leaching step will also significantly reduce the scale of the gravity circuit which can become complex and therefore costly as seen in Figure 1.

Flowsheets typical of tungsten Concentrator plant are shown in Figure 2 to Figure 5. These vary depending on ore mineralogy and the relative abundance and degree of liberation of Molybdenite, Scheelite and Wolframite. The process flowsheet for Riviera is shown in Figure 7. Testwork in 1981 did not investigate gravity concentration. Despite this, since all flowsheets include some form of gravity concentration the Riviera flowsheet includes a basic gravity section consisting of six J1800 Kelsey jigs configured as three roughing and three cleaning units.

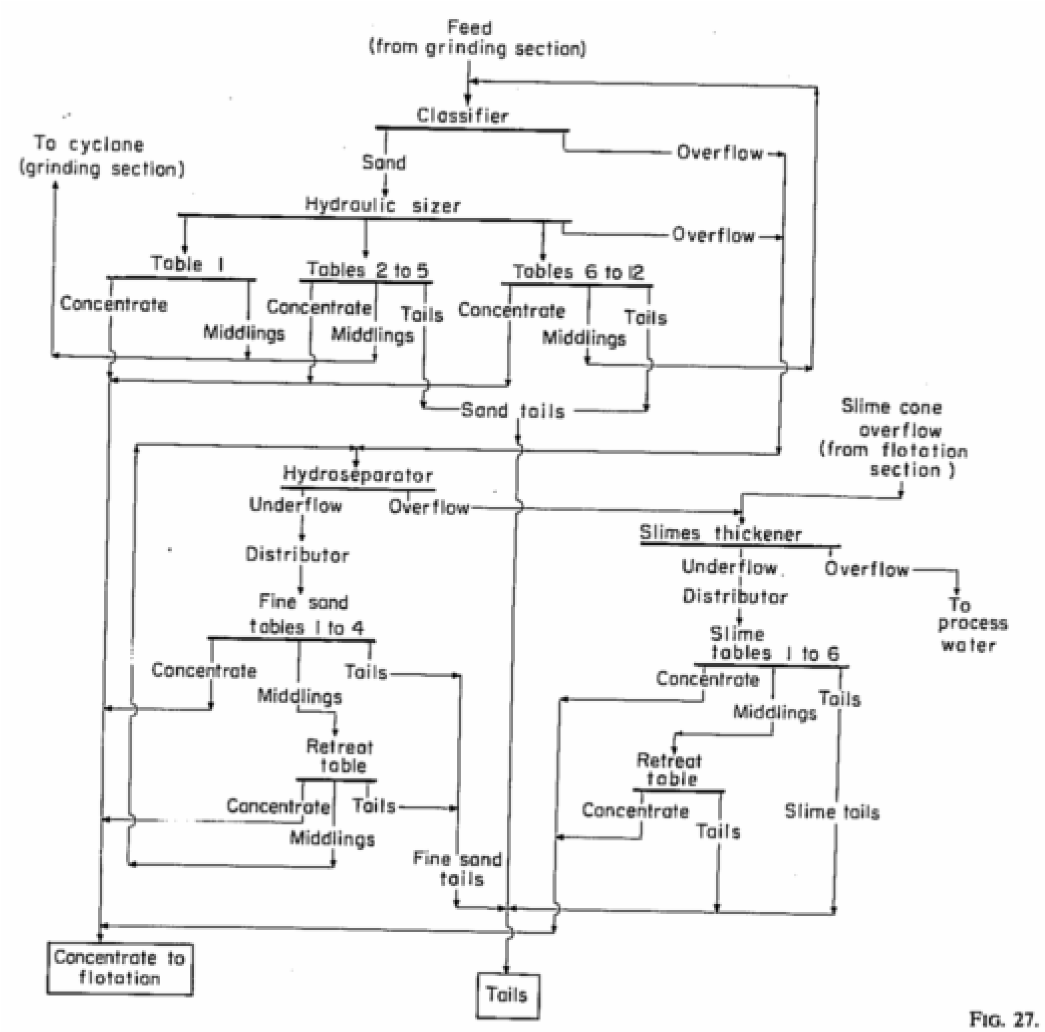


FIG. 27.

Figure 1 Typical Gravity Concentration Circuit

Geodex Minerals, Sisson Bank Deposit, New Brunswick, Canada

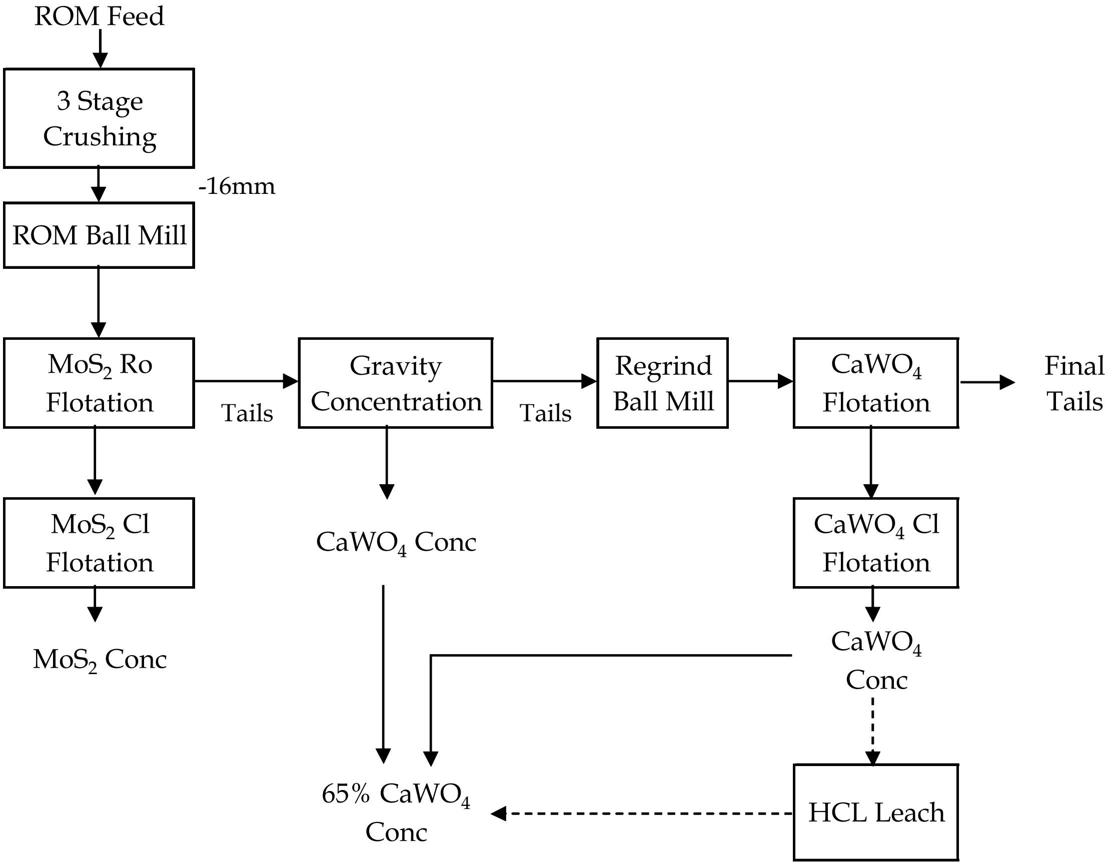


Figure 2 Sisson Bank Flowsheet

Strata Gold Corporation, Mar-Tungsten Deposit, Central Yukon, Canada

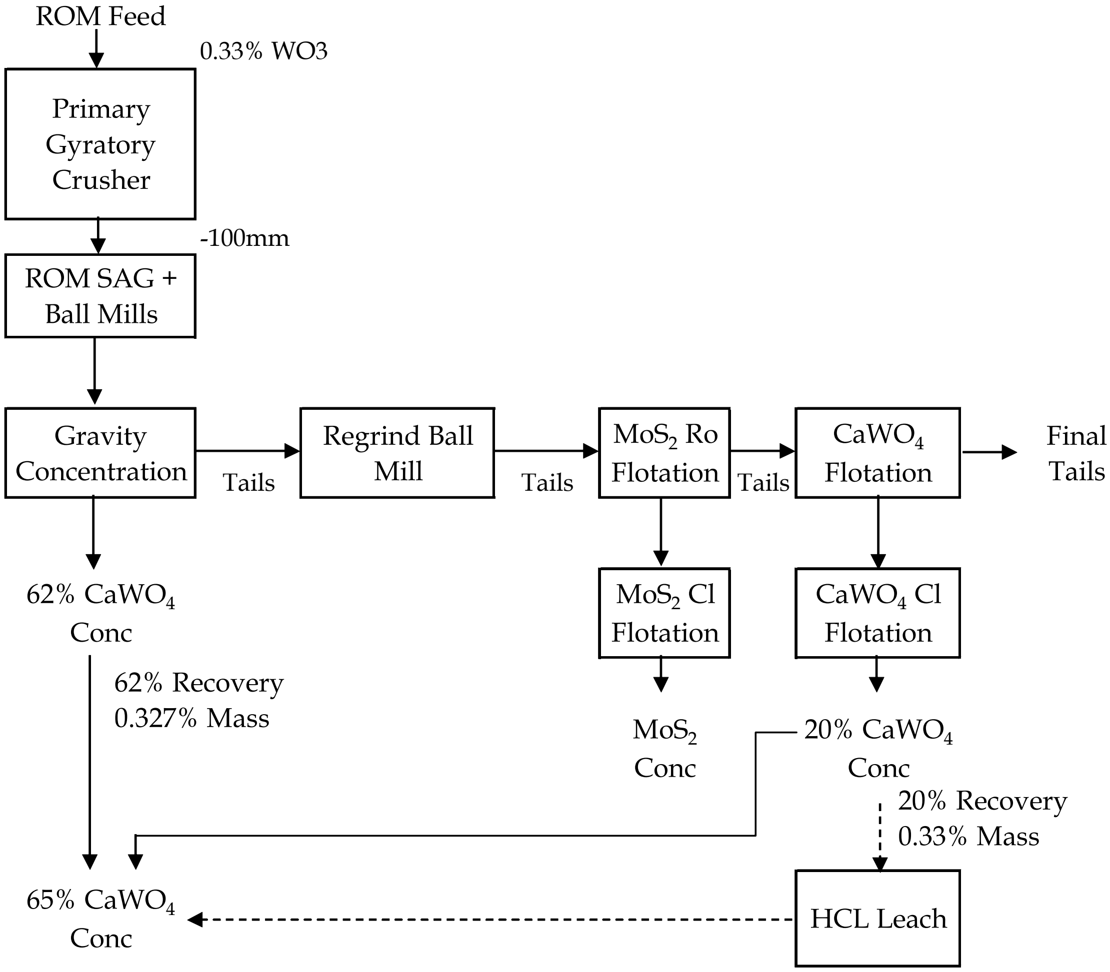


Figure 3 Mar-Tungsten Flowsheet

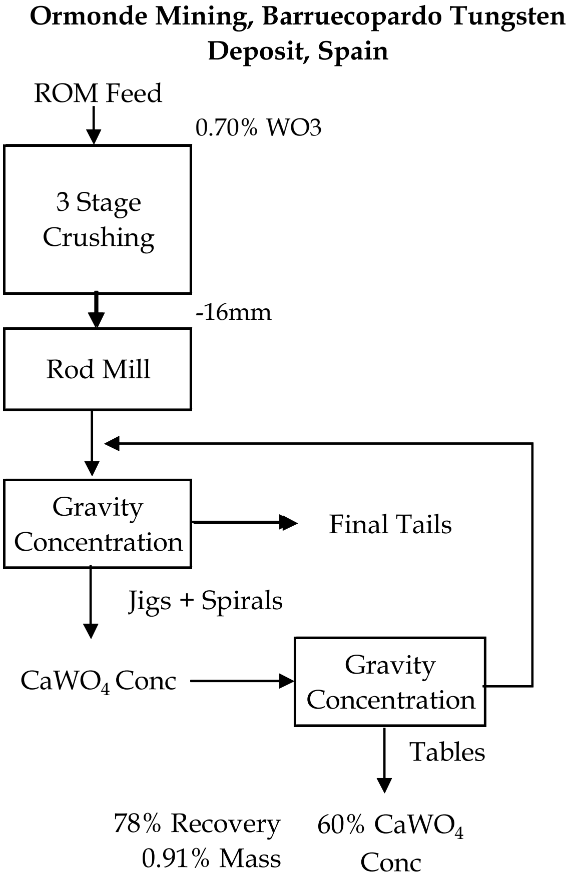


Figure 4 Barruecopardo Flowsheet

5.5 Concentrates Processing Plant producing Ammonium Paratungstate (APT)

Tungsten is not refined by smelting or in a manner similar to may other metals due to the fact that it has the highest melting point of any metal (3,422˚C). Tungsten is therefore extracted chemically to a partially refined state of APT [$(NH_4)10W_{12}O_{41}. 5H_2O$] which is the main tungsten raw material traded in the market as a powder. APT is usually calcined to yellow or blue oxide (WO_3 or $W_{20}O_{58}$).

Tungsten concentrate assaying 60-65% WO_3 may be further processed by either one of two routes to produce APT (see Figure 5),

a. An alkali soda ash in which tungstic acid (H_2WO_4) is formed followed by ammonical dissolution and crystallisation or

b. An alkali caustic soda leach route involving either solvent extraction or ion exchange and crystallisation.

Little information is available regarding these processes. However, it is understood that both involve dilute solutions with the result that the number and size of equipment will be large relative to the solids feed tonnage. This means that although throughput of the concentrates processing plant is only some 0.30-0.40% of the Concentrator, the size and cost of the plant will be proportionally larger relative to throughput (Table 5, section 7.2 shows capital cost to be about 10% of the Concentrator).

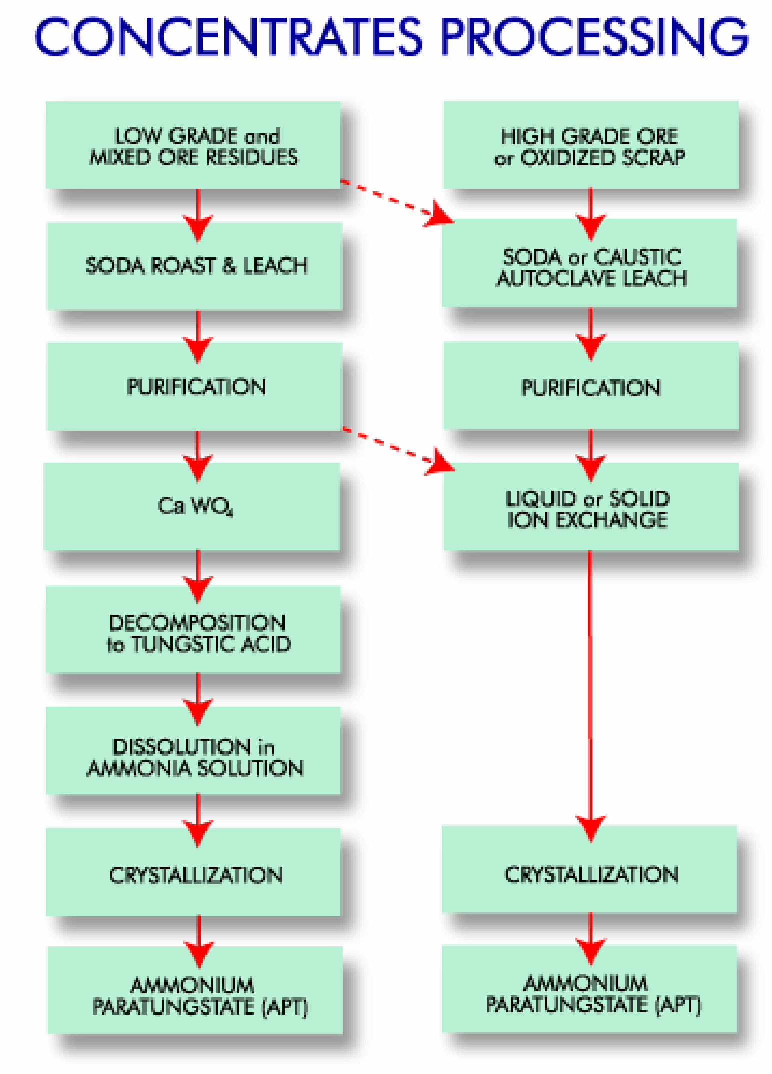


Figure 5 Flowsheet for Production of Ammonium ParaTungstate (APT)

6. MASS BALANCE AND LAYOUT OF PLANT

The plant mass balance is based on a throughput of 3.0 mtpa at a head grade of at 0.22% WO_3 and 0.020% Mo. The mass balance at the lower throughput of 0.70mtpa will have the same recoveries but at higher concentrate grades commensurate with the higher head grade of 0.31% WO_3 and 0.020% Mo. Mass pulls and solids flowrates will vary accordingly.

6.1 Concentrator Plant

Plant availability and throughput per hour is estimated as per Table 1. Design throughput is nameplate + 10%, i.e. 375t/hr + 10% = 415t/hr. Plant mass balance is detailed in Table 2. Molybdenum recovery is estimated at 60% and tungsten recovery at 80% into a flotation concentrate of 30% WO_3. The flotation concentrate is leached with acid to obtain a marketable grade of 60% WO_3 at a recovery of 76%.

The envisaged process flowsheet is presented in Figure 7. The flowsheet includes a gravity concentration section which has been based on Kelsey jigs.

Operating Hours and t/hr

tonnes/month	250,000
+10%	275,000
Days/month	30
Hours/day	24
% Availability Crusher	70
Crusher t/hr	546
% Availability Plant	92
Plant feed t/hr	415

Table 1 Concentrator Plant Availability and Throughput

	Stream	dry t/hr	% solids	water m^3/hr	pulp m^3/hr	% -75µm	% Mass	% MoS_2	% Recovery MoS_2	% WO_3	% Recovery WO_3
	Crusher Feed	546	95	29	211	5					
	ROM Mill Feed	415	95	22	160	5	100.00	0.020	100.0	0.22	100.0
	Primary Cyclone Feed	1,453	52	1,341	1,825	20					
Molybdenum Circuit	**Rougher Feed**	415	30	968	1,107	45	100.00	0.020	100.0	0.22	100.0
	Rougher Conc	2.1	18	9	10	65	0.50	2.80	70.0	1.32	3.0
	Regrind Mill Thickener Overflow			7							
	Regrind Mill Feed	2.1	50	2.1	2.8	65	1.00	1.44	72.0	0.66	3.0
	1st Stage Cleaner Feed	2.1	20	8	9	90	1.00	1.44	72.0	0.66	3.0
	Cleaner Tails	2.0	20	8	9	90	0.48	0.42	10.0	0.69	1.5
	Flotation Conc	0.10	20	0.4	0.4	90	0.023	52.0	60.0	14.30	1.5
	Conc Thickener Underflow	0.10	55	0.1	0.1	90	0.023	52.00	60.0	14.30	1.5
	Conc Thickener Overflow			0.3							
	Rougher Tails	414.90	30	967	1,105	45	99.98	0.008	40.0	0.22	98.5
Tungsten Circuit	**Rougher Feed**	414.90	30	967	1,105	45	99.98	0.020	41.1	0.22	101.4
	Rougher Conc	14.5	18	66	71	65	3.50	0.41	72.0	5.53	88.0
	Cleaner Tails	12.1	18	55	59	65	2.91	0.48	70.0	0.60	8.0
	Flotation Conc	2.43	20	9.7	10.6	65	0.587	0.068	2.0	30.0	80.0
	Conc Thickener Underflow	2.43	60	1.6	2.4	65	0.587	0.068	2.0	30.0	80.0
	Conc Thickener Overflow			8.1							
	Autoclave Conc	1.16					0.279	0.036	0.5	60.0	76.0
Gravity Separation and Tailings	**Rougher Tails**	412.5	30	957	1,095	45	99.4	0.008	39.1	0.047	21.4
	Tails Cyclone Feed	412.5	30	957	1,095	45	99.4	0.008	39.1	0.047	21.4
	Kelsey Jigs Feed	309	50	309	412	30	74.5	0.003	11.7	0.038	12.8
	Kelsey Jigs Conc	1.5	15	9	9	40	0.11	0.22	1.2	6.63	3.2
	Tailings Thickener Underflow	410.9	60	274	411	45	99.3	0.008	38.0	0.041	18.5
	Tailings Thickener Overflow			683							

Table 2 Mass Balance of Concentrator Plant

6.2 Concentrates Treatment Plant

WO_3 contains 79.3% tungsten and in a 65% WO_3 concentrate tungsten content is 51.6%. Producing ammonium paratungstate increases the tungsten content to 76.8% (96.8% WO_3). No information is available in the public domain regarding process details and mass balance. As shown in Figure 5 the production of APT is a hydrometallurgical process. Because of the nature of the feedstock and the chemical engineering nature of the concentration process, hydrometallurgical plants operate with a high recovery usually 97.0-99.0%. It is therefore assumed that recovery of tungsten will be 98% and recovery through to APT production is 74.5%.

A mass balance is shown in Table 3. Tailings would be returned to the Concentrator regrind mill.

	Stream	dry t/hr	% solids	water m^3/hr	pulp m^3/hr	% -75μm	% Mass	% MoS_2	% Recovery MoS_2	% WO_3	% Recovery WO_3
Concentrates Treatment Plant	**Autoclave Conc ex Concentrator Plant**	1.16					0.279	0.036	0.5	60.0	76.0
	APT	0.70					0.169			96.8	74.5
	Tailings	0.45					0.109	0.091	0.5	3.06	1.5

Table 3 Mass Balance of Concentrates Treatment Plant

6.3 Layout of Metallurgical Complex

The metallurgical complex is housed within an area 125m by 325m and consists of crushing and stockpile, flotation, gravity concentration, thickening and water storage, filtering, reagent make-up and storage, concentrates treatment plant, final products dispatch, stores, engineering workshops, outside lay-down area, security and offices. Layout is shown with 5m block gridlines in Figure 8 and without the gridlines in Figure 9.

7. SIZING AND COST OF PLANT

Plant size and costs has been based on a throughput of 3.0 mtpa. Costs at the lower throughput of 0.70mtpa have not been determined to the same level of accuracy, but ratioed according to the six-tenths rule.

The metallurgical operation has been sized for nameplate throughput of 3mtpa +10%. Equipment sizing for the Concentrator plant has been based on initial testwork, published flowsheets and equipment size and standard design metrics for a plant of this type.

Apart from the flowsheet in Figure 5, there is little available information for the Concentrates Treatment plant on which to base even an order of magnitude estimate of capital cost. However, an estimate has been made in line with the best information obtained.

Order of magnitude estimates are usually +/- 40% accuracy. In this case accuracy of capital and operating costs are viewed as follows;

- Concentrator:

  Equipment size is based on testwork and standard design practice. The cost of major items was obtained from local equipment suppliers. Operating costs was based on data from similar operations. Since throughput is based on nameplate + 10% it is unlikely that cost will exceed the stated amounts. Accuracy of cost is therefore defined as being in the range -30% + 10%,

- Concentrates Treatment Plant:

  Equipment size is based on vanadium hydrometallurgical plants, but is not as accurate as for the Concentrator. The cost of major items was obtained from the internet (see details in section 7.2). Operating costs are dependent upon the treatment route selected (ion exchange or solvent extraction) and the specific type of media and reagents used. These are unknown, thus it is conservatively assumed that operating costs are 50% of Concentrator Rands per tonne of ore milled. Accuracy of capital cost is not as good as for the Concentrator and is thus defined as being in the range -40% + 40%.

7.1 Capital Cost: Concentrator Plant @ 3.0 mtpa

Standard process engineering factors have been applied, such as 4.5% of the cost of major mechanicals for the cost general platework and pumps; the total cost of the Concentrator and infrastructure being 2.5x the cost of major mechanicals and power consumption of all pumps being equal to 8kW per t/hr.

The total cost of the Concentrator and infrastructure (offices, engineering workshops, stores etc) is estimated as R 909.5m (see Table 4).

ESTIMATE OF CONCENTRATOR COST

Circuit	Item	Number	Type	Size (each)		Total Absorbed kW	Cost (Rands)	
	Jaw Crusher	1	Single toggle	TST1550		260	8,289,500	
	Stockpile	1		20,000 t	48 hours		10,000,000	
	Primary Mill	1	Grate discharge	6.71mØ x 9.14m	7400 kW motor	6,500	100,000,000	
	Cyclone Cluster	1			Feed = 1875m^3		1,650,000	
Moly - bdenum Circuit	**Conditioners**	2		55m^3		75	1,500,000	
	Roughers	8	Wemco SmartCell	100m^3	Cylindrical cell	1,480	22,100,000	
	1st Stage Cleaners	6	Wemco 1+1	3m^3	Rectangular cell	66	3,200,000	
	2nd Stage Cleaners	4	Wemco 1+1	3m^3	Rectangular cell	44	2,300,000	
	3rd Stage Cleaners	3	Wemco 1+1	3m^3	Rectangular cell	33	1,900,000	
	Conc Thickener	1	E-CAT	2mØ	Ultra high rate	2	800,000	
	Regrind Mill Thickener	1	Hi-Rate	6mØ	High rate	6	1,300,000	
	Regrind Mill Surge Tank	1		30m^3		45	600,000	
	Regrind IsaMill	1			220 kW motor	150	20,000,000	
	Conc Storage Tank	1		3m^3		3	500,000	
	Conc Filter	1	Belt Filter	1m^2	Incl Vacuum syst	50	1,000,000	
Tungsten Circuit	**Conditioners**	2		55m^3		75	1,500,000	
	Roughers	8	Wemco SmartCell	100m^3	Cylindrical cell	1,480	22,100,000	
	1st Stage Cleaners	7	Wemco SmartCell	10m^3	Cylindrical cell	210	6,500,000	
	2nd Stage Cleaners	4	Wemco SmartCell	10m^3	Cylindrical cell	120	4,200,000	
	3rd Stage Cleaners	4	Wemco 1+1	3m^3	Rectangular cell	44	2,300,000	
	Conc Thickener	1	Hi-Rate	6mØ	High rate	6	1,300,000	
	Conc Storage Tank	1		25m^3		25	600,000	
	Leach Autoclave	1	Pressure	5m^3		20	4,800,000	
	Conc Filter	1	Belt Filter	16m^2	Incl Vacuum syst	120	6,000,000	
	Tailings Cyclone Cluster	1			Feed = 1100m^3			
	Tailings Thickener	1	Hi-Rate	40mØ	High rate	22	14,700,000	
	Kelsey Jigs	6	J1800			180	76,840,000	AUS$ 11.3m
	4.5% of above for general platework and pumps						14,219,078	
	Tailings Dam	1					84,000,000	
	Other drives (feeders etc)					100		
	Conveyors					200		
	Pumps (@ 8kW per t/hr)					3,320		
	Reagents					60		
	Lighting, Office, Welding					250		
					Total	**14,945**	**330,198,578**	
					Total installed equipment + building + tailings dam		**909,496,444**	
					(Total installed equipment + building = 2.5 x total mechanical cost)			

Table 4 Capital Cost of Concentrator

7.2 Capital Cost: Concentrates Treatment Plant for a 3.0mtpa Operation

Given the small feed tonnage of 1.16 t/hr to this plant the equipment handling solids will be quite small. However, at this stage the choice of route between ion exchange and solvent extraction remains open. Both unit operations involve dilute solutions and equipment for this part of the plant will therefore be quite large.

Equipment sizing has been based on hydrometallurgical plants treating vanadium and costs have been obtained from the Matches website (http://www.matche.com). Matches is a licensed small engineering company in Oklahoma, USA which provides conceptual process and cost engineering services to the chemical, energy, manufacturing and metallurgical industry.

ESTIMATE OF CONCENTRATES TREATMENT PLANT COST

	Number	Type	Size (each)		Total Absorbed kW	Cost (Rands)	http://www.matche.com/EquipCost
Leach Autoclave	1	Pressure	5m^3	Stainless 304	20	4,837,421	US$ 419,300 in 2007
Mixer/Settler	6		3m^3	Glass lined	12	8,396,554	US$ 121,300 in 2007
Heat Exchanger	1		20m^2	Stainless 304		518,007	US$ 44,900 in 2007
Drier	1		20m^2	Stainless 304	120	2,114,713	US$ 232,900 in 2007
Crystalliser	1		8m^3	Stainless 304	20	2,686,943	US$ 183,300 in 2007
Centrifuge	1		1mØ	Stainless 304	50	1,398,272	US$ 121,200 in 2007
Thickeners	3		2mØ		15	2,400,000	
Storage tanks	6		15m^3		90	2,160,000	
25% of above for general platework and pumps						6,127,978	
Other drives (feeders etc)					50		
Pumps (50% of toal absorbed for equipment)					164		
Reagents					60		
Lighting, Office, Welding					200		
				Total	**801**	**30,639,888**	
				Total installed equipment + building		**91,919,663**	
				(Total installed equipment + building = 3.0 x total mechanical cost)			

Table 5 Capital Cost of Concentrates Treatment Plant

7.3 Operating Cost for a 3.0mtpa Operation

Concentrator operating cost is based on other similar operations and current power, media, reagent and labour costs and is detailed in Table 7.

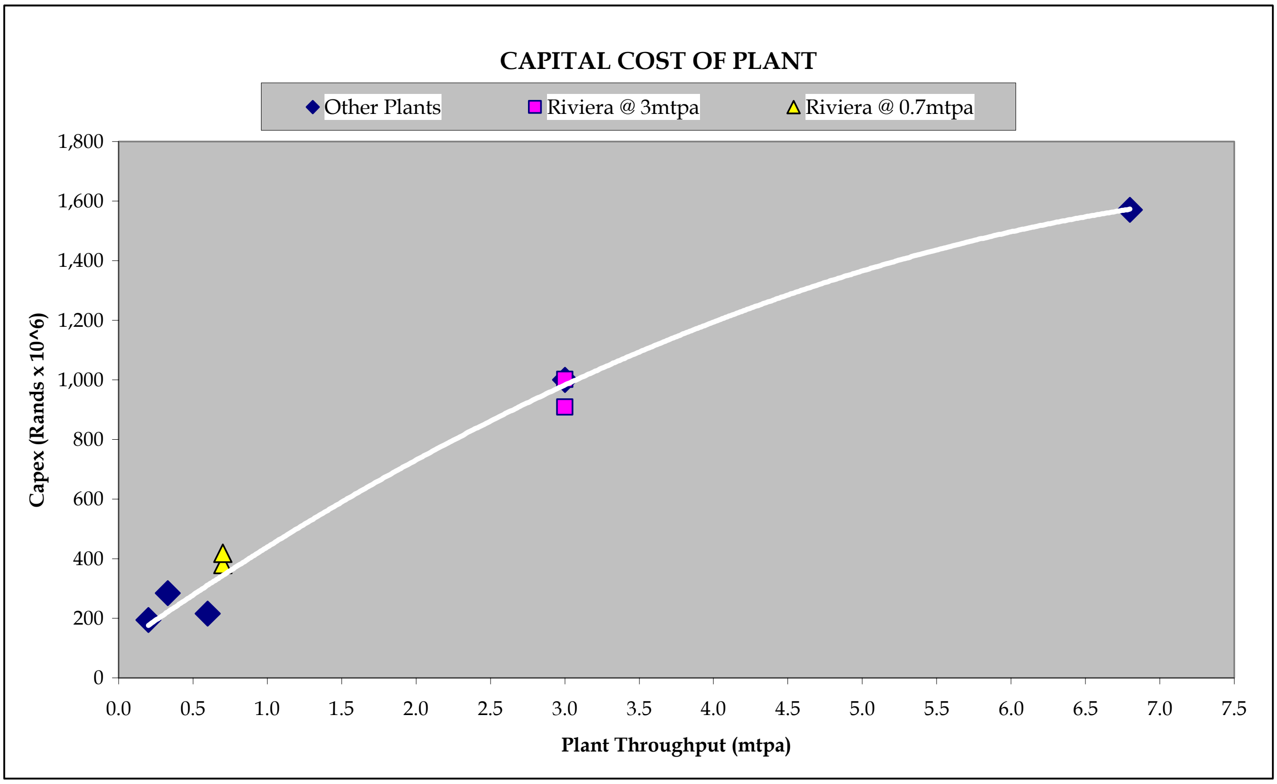
Both capital and operating costs are benchmarked against other operations in Table 6 and their relationships with throughput plotted in Figure 6. Unfortunately the various data sources did not specify whether the final product was flotation concentrate or APT. However, from Table 5 capital cost is about 10% of the Concentrator. For the throughput under consideration, estimated capital and operating costs are in-line with other operations.

In the absence of data to estimate operating cost it has been conservatively assumed that this is 50% of the Concentrator in Rands per tonne milled.

	Concentrator Throughput			Approx R/tpm (for capex calcn)	Approx Capex Rm	Approx Opcost R/t milled	
	mtpa	tpm	t/hr				
Barruecopardo	0.20	16,667	25	11,700	195		
Mt Pleaseant	0.33	27,500	41	10,327	284		
Cantung	0.40	33,333	50			515.0	US$51.5 @ R10.0/US$ in 2008
King Island Scheelite	0.60	50,000	75	4,300	215		
Hemerdon	3.00	250,000	375	4,000	1,000	54.3	AUS$7.39 @ R7/AUS$ in 2008
Riviera * (Concentrator only)	3.00	250,000	412	3,636	909	54.7	
Riviera * (Concentrator & Concentrates Treatment Plant)	3.00	250,000	412	4,004	1,001	82.1	
Sisson Brook	6.80	566,667	850	2,771	1,570	48.7	CAN$5.33 @ R8.5/CAN$ in Oct 2007

** Throughput = nameplate + 10%*
Source: Website company reports

Table 6 Operating Cost of Metallurgical Complex and Benchmarking of Capital Cost



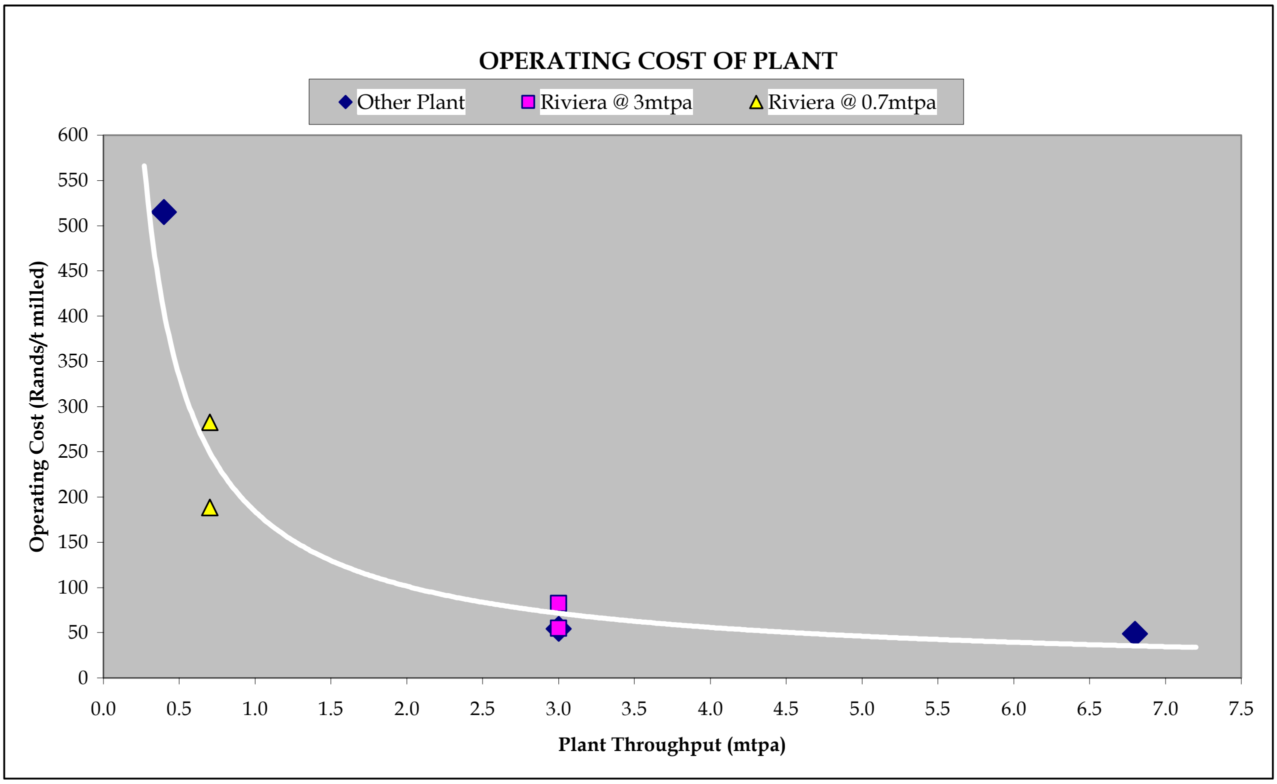


Figure 6 Graphical Representation of Capital and Operating Costs with Throughput

eurus mineral consultants

RIVIERA TUNGSTEN: CONCENTRATOR

Summary	R/t
Consumables	26.63
Labour	7.30
Power	13.74
Maintenance	7.00
Total	**54.68**

Consumables	Rate	Price	Opex
	g/t	R/kg	R/t
Steel balls	1,000	8.5	8.50
Mill liners	300	7.5	2.25
Collector	200	12.0	2.40
Frother	60	10.5	0.63
Promoter/Modifier	60	25.0	1.50
Unslaked lime	700	1.00	0.70
Acid	1,500	5.00	7.50
Flocculant	30	30.0	0.90
Water	750,000	0.003	2.25
			26.63

Power			R/t
Max. demand	R/kVA	13.00	
Max. demand	kVA	16,000	
Max. dem. charge	R	208,000	
Abs. power	kWh/month	10,760,400	
Power rate	R/kWh	0.30	
Power charge	R	3,228,120	
Total charge	**R**	**3,436,120**	**13.74**

Labour

Staff	Number	R each	R/t
Met. Manager	1	50,000	0.20
Plant. Supt	1	35,000	0.14
Plant foreman	1	22,500	0.09
Shift foreman	4	17,500	0.28
Lab technician	1	11,250	0.05
Day shift	8	10,000	0.32
Plant operator	24	8,750	0.84
Labour	36	5,000	0.72
Sampler	4	7,500	0.12
Engineer	1	37,500	0.15
Eng. foreman	1	25,000	0.10
Artisan	5	17,500	0.35
Aide	12	6,250	0.30
Total	98		**3.66**
Operating			
Metallurgical	90	708,001	2.83
Engineering	15	204,177	0.82
Total	105		**3.65**

Table 7 Operating Cost of the Concentrator Plant (R/tonne milled) for a 3.0mtpa Operation

7.4 Capital and Operating Costs: Concentrator Plant @ 0.7 mtpa

Costs for the smaller throughput is based on the six-tenths rule which assumes a direct relationship between capital cost (C) and capacity (Q) taken to the 6/10 power;

$$\frac{C_1}{C_2} = \left[\frac{Q_1}{Q_2}\right]^{0.6}$$

Capital and operating costs are shown in Table 8. Capital cost is estimated using the above equation to the 0.60 power. Since operating costs have a different relationship with capacity they are estimated using the above equation to the 0.15 power.

	Concentrator Throughput			Approx R/tpm (for capex calcn)	Approx Capex Rm	Approx Opcost R/t milled
	mtpa	tpm	t/hr			
Riviera * (Concentrator only)	0.70	58,333	96	6,508	380	188.5
Riviera * (Concentrator & Concentrates Treatment Plant)	0.70	58,333	96	7,364	430	282.7

** Throughput = nameplate + 10%*
Source: Website company reports

	Concentrator Throughput			Approx Opcost R/t milled	Total Opcost Rm/month
	mtpa	tpm	t/hr		
Cantung	0.40	33,333	50	515.0	17.17
Hemerdon	3.00	250,000	375	54.3	13.58
Riviera * (Concentrator only)	3.00	250,000	412	54.7	13.68
Riviera * (Concentrator & Concentrates Treatment Plant)	3.00	250,000	412	82.1	20.51
Riviera * (Concentrator only)	0.70	58,333	96	188.5	10.99
Riviera * (Concentrator & Concentrates Treatment Plant)	0.70	58,333	96	282.7	16.49
Sisson Brook	6.80	566,667	850	48.7	27.62

Table 8 Capital and Operating Cost of Metallurgical Complex for 0.70mtpa

8. APPENDIX

C.J. Menendez, V.L. Barone, I.L. Botto and E.L. Tavani, Physicochemical characterization of the chlorination of natural wolframites with chlorine and sulphur dioxide , *Minerals Engineering*, **Vol.20** No.14, 2007

S. Hairunnisha, G.K. Sendil, J. Prabhakar Rethinaraj, G.N. Srinivasan, P. Adaikkalam and S. Kulandaisamy, Studies on the preparation of pure ammonium para tungstate from tungsten alloy scrap, *Hydrometallurgy*, **Vol.85** No.2-4, 2007

J.I. Martins, Jose L.F.C. Lima, A. Moreira and S.C. Costa, Tungsten recovery from alkaline leach solutions as synthetic scheelite, *Hydrometallurgy*, **Vol.85** No.2-4, 2007

Guar, R.P.S., Modern Hydrometallurgical Production Methods for Tungsten, *JOM*, **Vol.58** No.9, 2006

Razavizadeh, H., and Iangroudi, A.E., Production of tungsten via leaching of scheelite with sulfuric acid, *Minerals & Metallurgical Processing*, **Vol.23** No.2, 2006

C. Kahruman, I. Yusufoglu, Leaching kinetics of synthetic $CaWO_4$ in HCl solutions containing H_3PO_4 as chelating agent, *Hydrometallurgy*, **Vol.81** No.3-4, 2006

Srinivas, K., et al, Studies on the application of alkyl phosphoric acid ester in the flotation of wolframite. *Mineral Processing and Extractive Metallurgy Review*, **Vol.25** No.4, 2004

Sreenivas, T., et al, An integrated process for the recovery of tungsten and tin from a combined wolframite-scheelite-cassiterite concentrate. *Mineral Processing and Extractive Metallurgy Review*, **Vol.25** No.3, 2004

L. Luo, L. Kejun, A. Shibayama, W. Yen, T. Fujita, O. Shindo, A. Katai, Recovery of tungsten and vanadium from tungsten alloy scrap. *Hydrometallurgy*, **Vol.72** No.1-2, 2004

B. D. Pandey, V. Kumar, D. Bagchi, R. K. Jana and

Premchand. Processing of Tungsten Preconcentrate from Low Grade Ore to Recover Metallic Values. *Mineral Processing and Extractive Metallurgy Review*, **Vol.22** No.4-6, 2000

J.P. Srivastava, P.N. Pathak. Pre-concentration: a necessary step for upgrading tungsten ore. *Int. J. Mineral Processing*, **Vol.60**, No.1, 2000

Table 9 References for Processing of Tungsten Ores

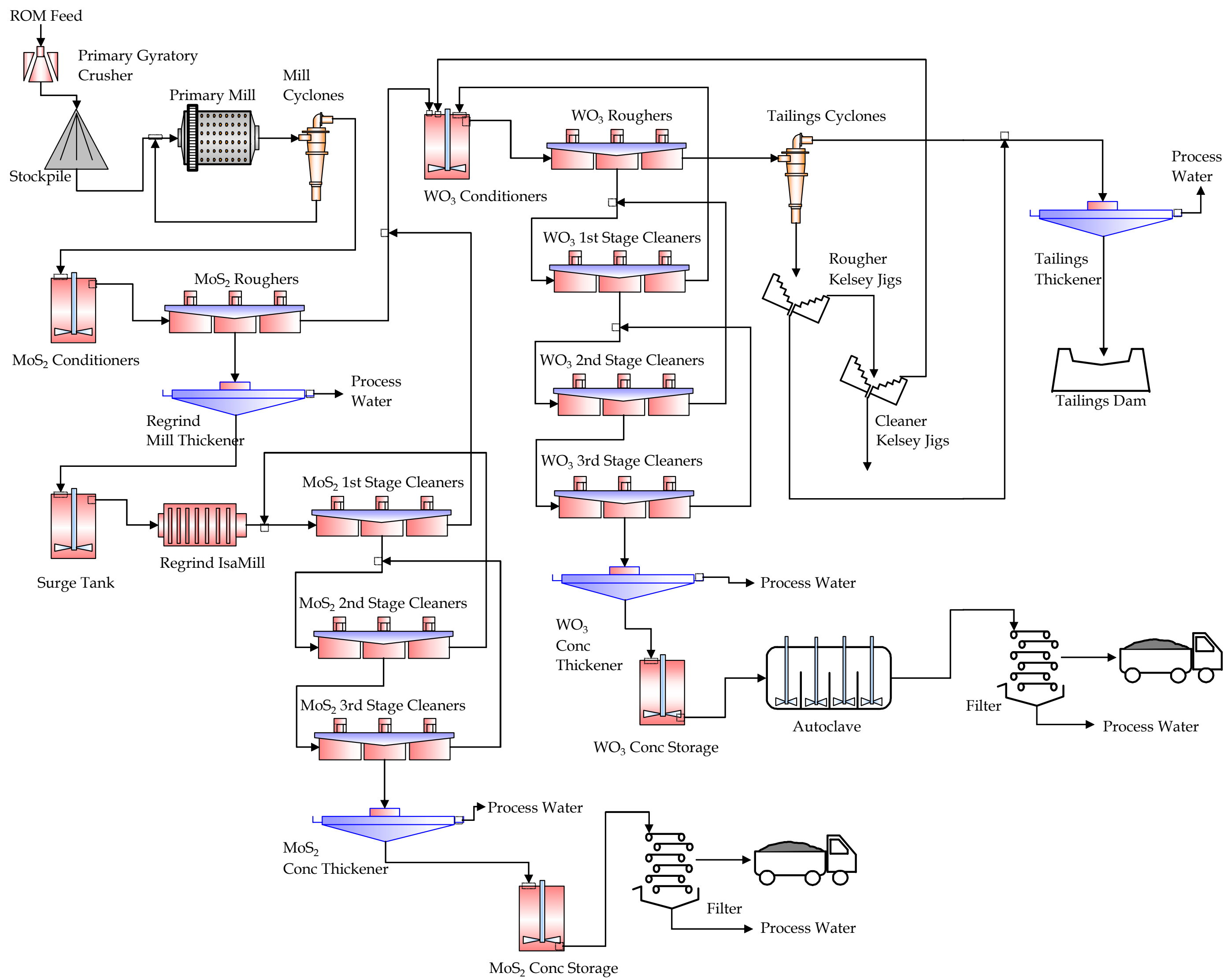


Figure 7 Concentrator Flowsheet

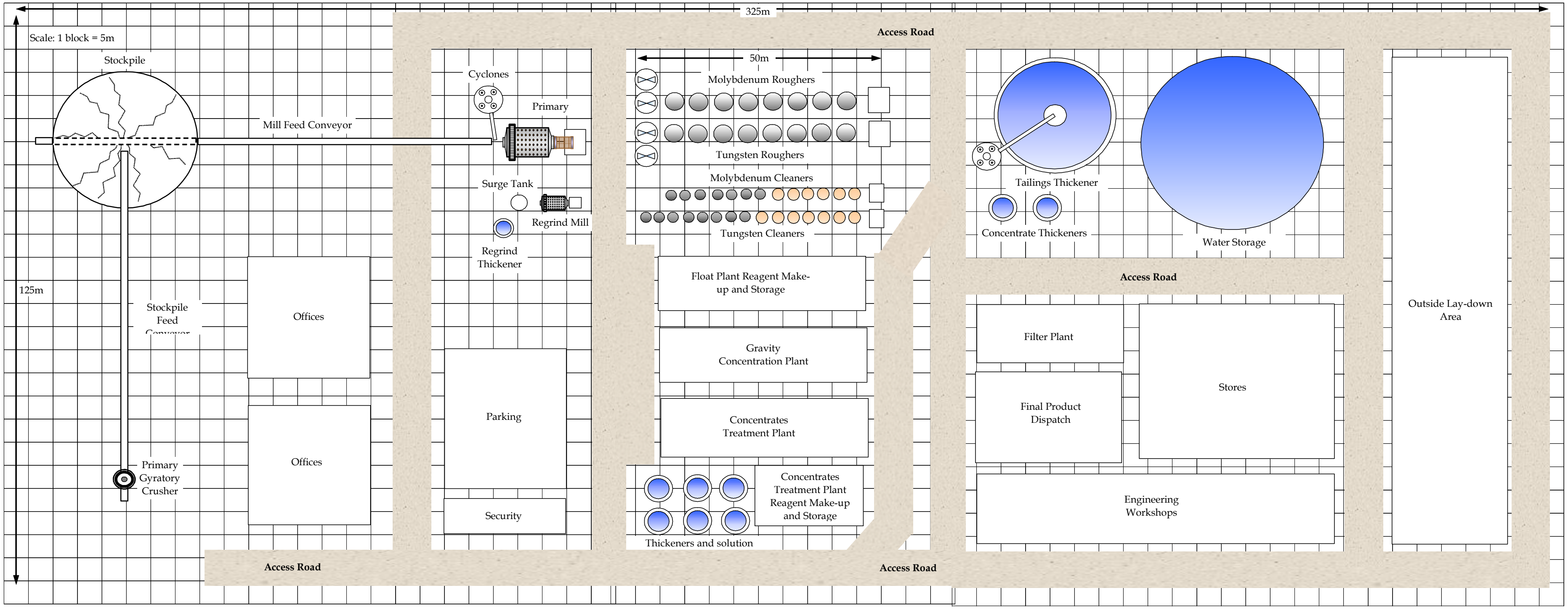


Figure 8 Layout of Metallurgical Complex (with 5m gridlines)

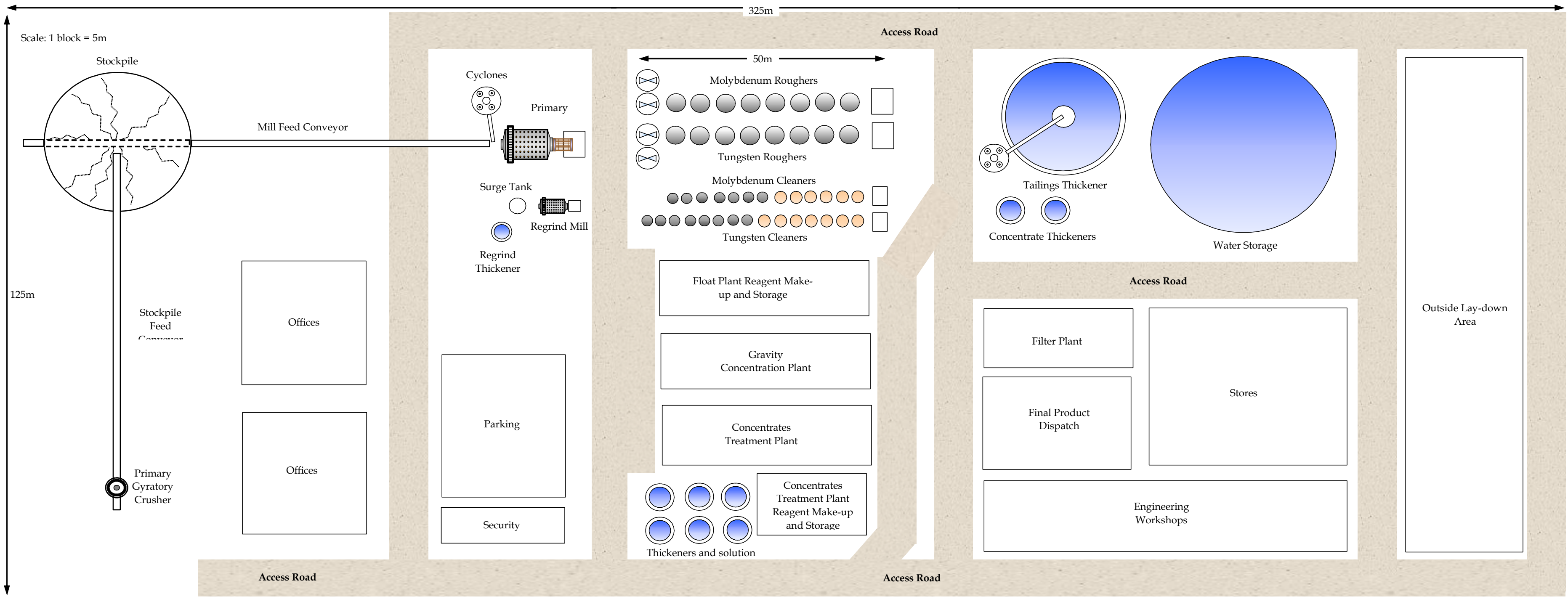


Figure 9 Layout of Metallurgical Complex (without 5m Gridlines)