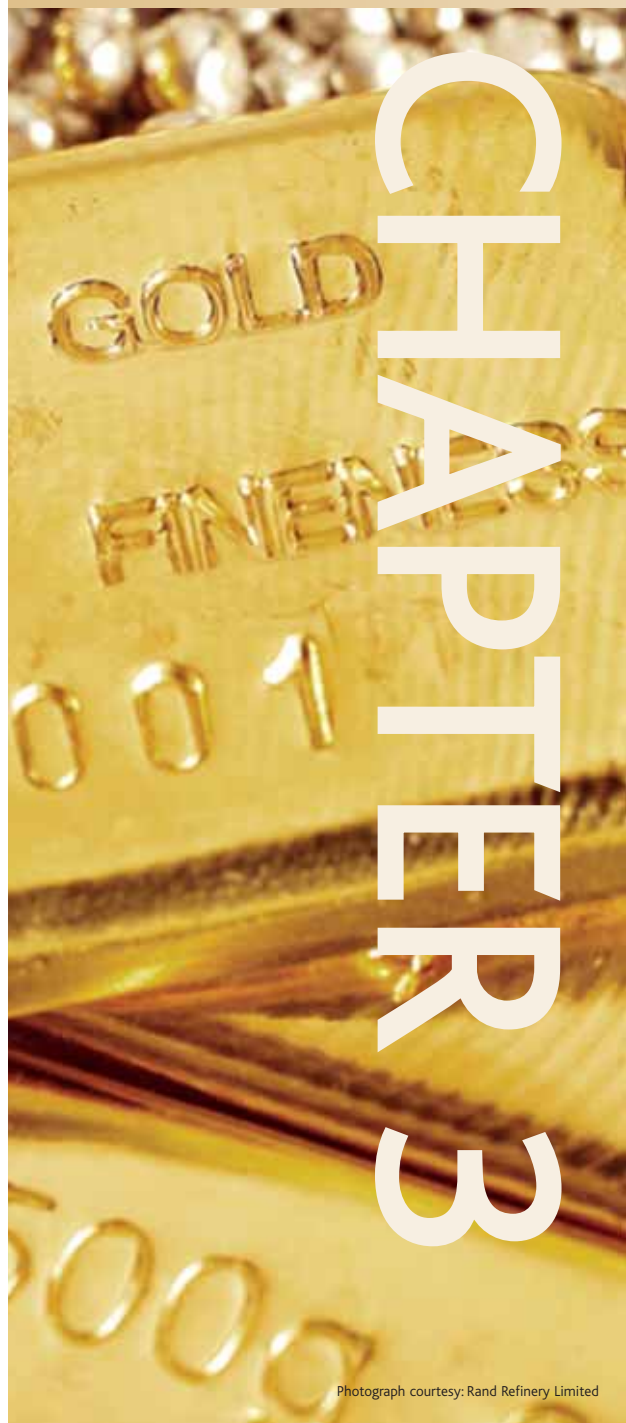




CHAPTER 3 DORÉ TO SEMI-FINISHED PRODUCT: REFINING AND RECYCLING



Photograph courtesy: Rand Refinery Limited

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CHAPTER 3

DORÉ TO SEMI-FINISHED PRODUCT: REFINING AND RECYCLING

Gold refining in South Africa is concentrated in the hands of two participants, Rand Refinery and Musuku Beneficiation Systems...

There are at least another seven known, but very small refiners in the country...

Illegal smelting houses and informal refiners operate in and around the vicinity of the country's gold mines...

In 2004, the primary refiners and recyclers treated 445t of fine gold...

3.1. INTRODUCTION

In terms of both value and volume, gold refining in South Africa is concentrated in the hands of two primary participants: Rand Refinery Ltd and Musuku Beneficiation Systems¹. Throughout this chapter, they are referred to as the primary refiners. There are a number of fundamental differences between the two refiners in terms of their history, ownership, feed, business structures, services and products, which are discussed in more detail.

In addition to the primary refiners, there are at least another seven known, but very small², refiners operating in the country. While three of these companies report that they refine output from the small-scale and informal mining sectors³ and material arising from dump treatment, all seven small refiners concentrate on the recycling of old gold jewellery scrap and process scrap generated during the jewellery manufacturing process, as well as medical and dental waste containing recoverable precious metals. Throughout this chapter the small refiners are referred to as recyclers.

Interviews with industry sources revealed that there are a number of illegal smelters and refiners operating in and around the vicinity of the country's gold mines. The activities of these illegal operations are not quantifiable and have not been accounted for in the statistics and analysis that follow. They do not form part of the formal value chain as described in this review.

Detailed interviews were conducted with six of the sector participants, including the two primary refiners. The results indicate different business structures; the primary refiners being distinct from the recyclers in the volume of metal refined, as well as in terms of cost structures, material and feed sourcing, customer bases and end products.

3.2. SUMMARY OF THE SOUTH AFRICAN GOLD REFINING INDUSTRY

In 2004, the formal sector primary refiners and recyclers treated 445t of fine gold. The breakdown of the origins of this fine gold and what it was used for are shown in the following table.

Flows of gold to and from the refiners and recyclers in South Africa in fine gold 2004

Gold to refining from:	t	%
South African mine output	328.9	73.8
Other mine output (Non-RSA) ¹	100.5	22.6
Dump treatment (RSA) ²	13.1	2.9
Secondary recycling ³	2.8	0.7
Total	445.3	100.0

Gold from refining to:

400oz bars	198.2	44.5
Kilobars and other bars	234.5	52.7
Local jewellery manufacture	9.6	2.2
Coins	2.9	0.7
Dental alloys	0.05	0.0
Electronics	0.01	0.0
Total	445.3	100.0

Note: Totals are net of process scrap

Data source: Virtual Metals.

Notes:

1. Other mine output originates from countries other than South Africa. See Chapter 2 for details of this gold production.
2. Dump re-treatment is the reprocessing of previously mined waste.
3. Recycling is the processing of gold-containing material such as electronic waste and old jewellery scrap but excludes fine gold contained in scrap generated during the process of jewellery manufacture, termed processing scrap. These sources of gold for refining are dealt with in more detail later in this chapter.

¹ See individual company profiles in the Research Directory as well as the rest of this chapter for further details.

² Small in terms of refining capacity and output, measured in kilograms rather than tons.

³ No details were given with respect to this specific source of gold. Chapter 2 deals with the small-scale gold miners operating in South Africa.



By far the majority of refined gold output (97% in 2004) is made into bars of various specifications. The bars were all exported directly to customers (mainly in India and Dubai), and also to the international bullion banks (mainly in London and Europe).

A further 9.6t of fine gold (or 2.2% of total gold refined) was fabricated into products for the jewellery sector, such as grain, plate and wire⁴. This percentage refers to total gold refined in South Africa, which includes output from mines outside South Africa. Of mine output from South Africa only⁵, the percentage of gold fabricated into jewellery by local manufacturers in 2004 was 2.9%.

In 2004, a further 2.93t (or 0.7% of total gold refined) was struck into coinage and the final 0.05t was applied to industrial and medical applications. Chapter 5 provides further details on gold coins and industrial applications.

3.3 SOUTH AFRICAN REFINING IN AN INTERNATIONAL CONTEXT

3.3.1 The LBMA

The London Bullion Market Association (LBMA) represents the interests of those international gold dealers, traders and bullion banks operating through the London gold market⁶. It was established in 1987 and issues a list of accredited refiners of which there are currently 56 around the world. These are refineries that have met specific criteria with respect to their refining standards and the quality of their products, and have been awarded London Good Delivery status⁷, giving them international recognition for quality and purity.

The main requirements for achieving London Good Delivery status are:

- a record of at least three years of producing refined metal;
- production of a minimum of 10t of gold and/or 30t of silver per annum;
- a net worth of at least £10 million;
- evidence of ownership and directors;
- a suitable endorsement from the central bank in the refiner's country of operation; and
- proven and consistent quality and purity of product.

Until recently, the Rand Refinery was the only South African operation with LBMA accreditation. Musuku Beneficiation Systems was awarded LBMA accreditation in September 2005. Rand Refinery is also one of only five refineries in the world to have been appointed by the LBMA as a Good Delivery Referee, responsible for the testing of samples from Good Delivery refiners in support of the LBMA's Good Delivery system.

In March 2005, Rand Refinery received Dubai Good Delivery Status.

3.3.2 Placing South Africa in a global context

Placing South African refining in a global context is not a simple task. Information on precious metals refining, market shares, installed capacity and capacity utilisation is considered proprietary and is difficult to obtain. An additional problem relates to identifying complete records of refining operations internationally. While it is possible to construct a database covering the known primary refiners and recyclers, there are literally hundreds of smaller operations whose business profiles cover a wide range of product lines, but which are essentially involved with the recycling of gold scrap⁸. This is particularly true of areas like the Indian sub-continent where such operations (dealing most commonly with less than 1kg of gold per annum) operate outside the formal sector.

In 2004, 97% of refined gold output was made into bars...

Only 2.2% of total gold refined was purchased by South African jewellery manufacturers...

Both Rand Refinery and Musuku Beneficiation Systems have achieved LBMA accreditation...

Rand Refinery is one of only five refineries in the world to have been appointed by the LBMA as a Good Delivery Referee...

⁴ This tonnage is net of process scrap and Chapter 4 deals with the topic in more detail.

⁵ Excluding secondary recycling and mine supply from other countries refined in South Africa but including local dump re-treatment.

⁶ The LBMA publishes gold and silver turnover through the London market and these are charted Appendix 4.

⁷ London Good Delivery status has become an international benchmark of quality and purity as it applies to refineries and their products.

⁸ A class of operations in South Africa that this review defines as the recyclers.

CHAPTER 3

DORÉ TO SEMI-FINISHED PRODUCT: REFINING AND RECYCLING

Review draws on global database comprising 162 known refineries...

Africa accounts for 8% of the world's gold refineries...

... and 12% of global refining capacity...

In 2004, global gold refining capacity utilisation was estimated at 55%...

This review draws on a global database consisting of 162 known refineries⁹ and recyclers. It analyses only commercial operations within the formal sector for which it is possible to obtain data. This global database also includes precious metals recovery associated with base metal refining, for example, gold and silver recovery from copper, lead and zinc refineries.

The three tables that follow present the analysis on a broad regional basis, although it should be noted that in the figures quoted for Africa, South Africa predominates. Apart from the South African refineries, there is also limited refining capacity in Zimbabwe. The figures for Africa also include three South African refineries that process PGM concentrates containing gold as a by-product.

Regional comparisons show that an estimated 8% of the world's gold refineries are found in Africa.

Refining summary (number of refineries)

	Number	%
Africa	13	8
Asia and Indian sub-continent	36	22
Australasia	7	4
Eastern Europe	12	7
Latin America	13	8
Middle East	4	3
North America	29	18
Western Europe	48	30
Total	162	100

Data source: Virtual Metals.

3.3.3 Capacity and capacity utilisation

The 162 global refining operations collectively have the capacity to treat 6,652t of fine gold per annum. The regional breakdown of this capacity is tabulated below:

Refining summary (% global capacity)

	t	%
Africa	772	12
Asia and Indian sub-continent	1,027	15
Australasia	341	5
Eastern Europe	662	10
Latin America	207	3
Middle East	775	12
North America	778	12
Western Europe	2,091	31
Total	6,652	100

Data source: Virtual Metals.

Of this total, Africa represents 11.6% (or 772t) of which South African refining capacity represents 98% (or 757t).

In 2004, global gold refining capacity utilisation was estimated at 55%¹⁰. This figure is somewhat higher than historical global capacity utilisation averages of 45%-52%. The reason for this increase is that, in 2004, larger than normal amounts of secondary material were returned for refining in direct response to higher Dollar gold prices, especially during the second half of the year.

⁹ Including the 56 operations that have LBMA London Good Delivery Status.

¹⁰ Virtual Metals estimates global mine supply and secondary recycling at 3,657t in 2004.

Refining capacity utilisation also shows some regional variances.

Refining summary 2004

	Output (t)	Capital utilisation (%)
Africa	475	61
Asia and Indian sub-continent	454	44
Australasia	928	37
Eastern Europe	185	28
Latin America	105	51
Middle East	155	20
North America	436	56
Western Europe	920	44
Total	3,657	55

Data source: Virtual Metals.

In this context, the following should be noted:

- Africa's capacity utilisation is slightly higher than other regions. This is because Rand Refinery has in recent years won refining contracts with mines in Ghana, Mali and Tanzania, and in its financial year ending September 2004, processed 142t of fine gold from African countries outside South Africa¹¹;
- although Eastern Europe (the former CIS) has substantial installed capacity, refineries based in these countries are forbidden by law to tender for international refining contracts and have to rely on local feed;
- Western European capacity utilisation has increased since the closure in 2004 of Johnson Matthey's Royston plant in the United Kingdom; and
- capacity utilisation in the Middle East is particularly low since this data includes three new refineries able to treat a total of 700t gold per annum recently commissioned in Dubai.

Irrespective of variations in regional capacity utilisation, the global gold refining industry remains in a state of over-capacity and this has been the case for many years. Despite this, there have been newcomers to the industry, for example Musuku Beneficiation Systems in South Africa and the new refineries based in Dubai. Consequently, tenders for refining contracts are aggressive, with treatment terms¹² offered by the refineries being particularly competitive. When tendering for international primary production, the refineries attempt to improve their tenders by offering attractive insurance and transport terms.

3.4 OVERVIEW OF THE LOCAL REFINING INDUSTRY

Analysis of the known refineries in South Africa highlights two distinct market sectors, namely the two primary refiners and the recyclers. Fact sheets detailing the business profiles and product lines of the two primary refineries and four of the recyclers can be found in the Research Directory.

3.4.1 Primary refiners

Rand Refinery has been in existence since 1921 and is the result of a collaborative effort by the major South African gold producers. Musuku Beneficiation Systems is a relative newcomer to the business having been established in 1997, when Harmony withdrew from Rand Refinery.

Harmony collaborated with minerals technology service provider Mintek in 1997 to build a small-scale plant that was later expanded with funding from European defence contractor BAE Systems, which supported the project as part of its defence contract offset obligations as overseen by the Department of Trade and Industry.

The rationale behind the decision to establish Musuku was based on two premises.

- Harmony believed that it was possible to differentiate Harmony's gold output from that of other gold producers and to brand its bar products, and that as a result the company could secure a premium for its products.

Africa's capacity utilisation is slightly higher than other regions...

The global gold refining industry remains in a state of over-capacity, as has been the case for many years...

Rand Refinery has been in existence since 1921 and is the result of collaborative effort of major South African producers...

¹¹ Data source: Rand Refinery 2004 Annual Report. It should be noted that figures cited in the review relate to calendar years, and thus this Rand Refinery figure is not directly comparable.

¹² See later in this chapter for further details on treatment terms.

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Rand Refinery is owned by AngloGold Ashanti (53%), Gold Fields (33%), DRDGOLD (10%), Avgold (2%) and Western Areas (2%)...

- Harmony believed that it would be cost-effective to refine its own output. Rand Refinery still treats Harmony's silver production and has assisted Harmony with its gold refining throughput when process problems at Musuku have required Harmony to process gold at Rand Refinery.

While Musuku Beneficiation Systems is 100% owned by Harmony Gold Mining, the ownership structure of Rand Refinery is as follows:

Rand Refinery ownership (September 2004)

	%
AngloGold Ashanti	53
Gold Fields	33
DRDGOLD	10
Avgold	2
Western Areas	2

Data source: Rand Refinery Ltd.

The table below summarises the differences in technology usage, funding, products and client base between the two.

Differences between the two primary refiners

	Rand Refinery Limited	Musuku Beneficiation Systems
Date established	1921	1997, expanded in 2000
Funding	Shareholders	Harmony Gold, Mintek and BAE Systems (latter funded expansion only)
LBMA London Good Delivery Status	Yes	Yes 2005
LBMA Good Delivery Referee Status	Yes	No
Refining Process	Miller Chlorination	Minataur
Smelting	Yes	No
Carbon Incineration	Yes	No
Silver Electro-refining	Yes	No
Gold Electro-refining	Pending	No
Refinery Feed	Doré	Cathode Slime
Feed Source	Shareholders' production plus competes internationally for doré and other material	South Africa (Harmony operations only)
Product Range:		
400oz Good Delivery Bars	Yes	Not originally - only recently awarded LBMA status
Kilobars	Yes	Yes
Other bars	Yes	Yes
Legal tender coins	Yes	No
Coin blanks	Yes	No
Jewellery alloys	Yes	Yes
Dental alloys	Yes	Yes
Assaying services	Yes	No
Location	Guateng, urban	At Harmony mine in Free State

Data source: Interviews.

98% of Musuku's feed is in the form of cathode slime, a product of electro-refining¹³. Rand Refinery's feed is 90% doré¹⁴ and the balance primarily cathode slime. Rand Refinery also treats mine output from non-South African mines in Ghana, Mali, Tanzania and Argentina, and as such is an exporter of refinery services. Musuku's feed is sourced only from Harmony group gold production in South Africa.

The recycling of old jewellery scrap, jewellery sweepings, medical and dental waste and electronic scrap represents a small proportion of the feed taken by the primary refiners. In volume terms, this secondary feed accounts for 2% of the refineries' throughput.

Both refineries reported that increasing volumes of electronic scrap were becoming available in the local market. Currently only Rand Refinery has the ability to treat this material.

For Rand Refinery, gold represents 96% of the company's turnover by value. The balance is made up from silver. For Musuku, in value terms, the gold to silver ratio is lower than that of Rand Refinery at 85% gold and 15% silver. The difference between the two is a reflection of the different primary feed the refineries receive from their mining clients.

Kilobars that are exported directly into India make up in excess of 95% of Musuku's final product. A further 1% is made up of bar products other than kilobars such as 100g bars. This output is also destined for export, to the Indian sub-continent, the Middle East or the Far East. The remaining 4% of Musuku's output is destined for the local market in the form of jewellery alloys and a limited amount of dental alloys.

Rand Refinery shows a similar high volume export business with 400oz bars for the London market, and kilobars and 100g bars, primarily for the Indian market, (either directly or indirectly via the major international bullion banks), as well as Switzerland, Italy, Turkey and Dubai. The small bars and 400oz bars make up some 97% of Rand Refinery's product line. The global destination of Rand Refinery's products is shown in the graph on the right.

Rand Refinery and Musuku between them account for an estimated 65% of the kilobar and small-bar market in India with other international primary refiners, such as Pamp SA, Argor-Heraeus SA, Metalor Technologies International SA, Valcambi SA and Australian Gold Refineries (AGR) making up the balance. The profit margins achieved on kilobars and small bars¹⁵ are low, and in order to maintain overall profitability, the refiners need to sell and ship gold bar products in large volumes.

3.4.2 Recyclers

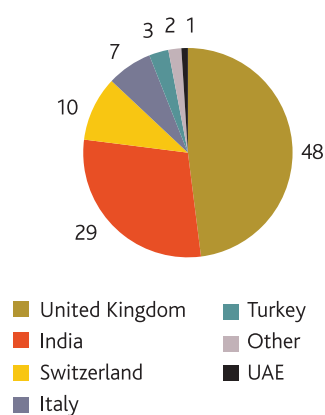
There are seven known recyclers formally operating in the gold business in South Africa, as well as an unknown number of illegal operations in existence, largely in and around the vicinity of the mines, processing stolen gold, ore and gold concentrates. Only information relating to the seven known recyclers has been included in this discussion.

Cumulatively, the seven recyclers have the capacity to treat and return to the local market just under 2t of fine gold per annum. In 2004, they supplied 1t of fine gold which was destined for the jewellery manufacturing industry.

98% of Musuku's feed is in the form of cathode slime; 90% of Rand Refinery's feed is doré...

Recycling represents a small portion of feed by primary refiners...

Destination of Rand Refinery products 2004 %



Data source: Rand Refinery, 2004 Annual Report.

Cumulatively, the recyclers have the capacity to treat and return to the local market just under 2t of fine gold per annum...

¹³ Electro-refining: the metal to be purified is made the anode in an electrolytic cell and it is dissolved by the application of a current into a usually acidic aqueous electrolyte or a molten salt. At the same time, the pure metal is deposited on the cathode. The process is carried out under conditions such that most impurities will either precipitate as 'sludge' or remain dissolved in the electrolyte.

¹⁴ The product of the smelting process sent for further refining the content of which varies but normally contains at least 85% gold.

¹⁵ See the product list in the Rand Refinery fact sheet for details.

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Secondary recyclers are all family-owned businesses...

In 2004, the refining and recycling sectors in South Africa directly employed 532 people...

Primary refiners, on a weighted average basis, produce more than six times as much fine gold per staff member as the recyclers...

Research showed a range of different business practices, customer bases and product lines, with each recycler operating in a different niche of the business. Examples include:

- recyclers whose core business is assaying but who will also treat precious metals scrap;
- recyclers who treat mainly medical waste to recover silver but who will also take jewellery sweepings and process scrap;
- recyclers who deal only with the jewellery industry and will not treat industrial waste;
- recyclers who operate out of one regional centre only, serving only local jewellery manufacturers;
- recyclers who have their main processing plant in one region, gather material from around the country and thus service a wide network of clients from the major jewellery manufacturing areas; and
- recyclers servicing only the very small jewellery manufacturers who use fine gold measured in grams.

These recyclers are all privately operated businesses that are family-owned.

3.5 EMPLOYMENT PROFILES

The collective gold refining and recycling sectors in South Africa directly employed an estimated 532 people in 2004.

Demographic profile of primary refiners and recyclers

2004	Primary refiners	Recyclers	Total
Total Employees	323	209	532
Men (%)	83	64	76
Women (%)	17	36	24

Data Source: From interviews.

On a weighted average basis, the gold refining and recycling industry is male-dominated (76% of all employees are men). The gender ratio in the primary refineries is 83:17 (men to women) and in the recyclers this ratio is 2:1 in favour of men.

Primary refiners on a weighted average basis produce more than six times as much fine gold per staff member as the recyclers, at 38kg and 6kg respectively, indicating the economies of scale of operating a large refinery compared with the small recycling plants.

Half the staff members working in the primary refineries are black.

Racial profile (%)

	Primary refiners	Recyclers	Total
White	43	43	43
Black	50	31	42
Coloured	5	26	14
Indian	2	0	1
Total	100	100	100

Data source: Interviews.



The educational profile of employees within the refiners and recyclers is shown below:

Education (%)			
	Primary refiners	Recyclers	Total
No matric	26	30	27
Matric	22	32	26
Tertiary	52	38	47
Total	100	100	100

Data source: Virtual Metals analysis of interviews

Tertiary education includes diplomas or non-university post-matric training from universities of technology (previously called technikons).

The higher level of tertiary qualifications among employees within the primary refiners reflects the skills levels needed to ensure smooth production and fabrication as well as to run the laboratories and assaying facilities.

While some of the recyclers may not offer assaying as a service to clients, they still complete assays for internal purposes and therefore employ a percentage of laboratory staff or technicians.

Job descriptions (%)		
	Primary refiners	Recyclers
Admin	16	20
Sales	3	25
Lab/Tech*	22	22
Management	17	14
Production	42	19
Total	100	100

Data source: From interviews.

* Technical refers to assaying staff, metallurgists and laboratory technicians.

The recyclers employ a high proportion of sales staff relative to their administrative staff. These figures include company representatives who spend much of their time on the road servicing a network of clients. Their primary role is the collection of jewellery scrap and the marketing of their recycled alloys. Since the primary refiners rely on large gold mining companies for the greatest part of their refining feed, they have less need for sales and marketing staff to service such business.

3.6. PRODUCT RANGE

The primary refiners offer a range of semi-finished and finished fine gold products. These products include bars, coins, jewellery alloys and dental alloys. The recyclers focus mainly on the production of commonly used jewellery alloys.

47% of employees in the refining and recycling business have a tertiary qualification...

Recyclers employ a high portion of sales staff relative to administrative staff...

Refiners offer a range of semi-finished and finished fine gold products, while recyclers focus mainly on the production of commonly used jewellery alloys...

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Gold bars are either minted or cast...

In 2004, sales of gold bars from South Africa were predominantly kilobars (51%)...

3.6.1 Bars

Gold bars are either minted or cast:

- cast bars are manufactured by the casting of molten gold into a mould of specific dimensions. The identifying marks¹⁶ are then applied manually or by press; and
- minted bars are struck from blanks (templates) that are stamped out of specific dimensions from a flat strip of gold in the same way as coins are struck from blanks. Identifying marks are usually applied during the minting process. Like gold coins, the dimensions of minted bars are precise.

In addition to these broad definitions, the international gold industry also classifies gold bars by weight with 'large' bars weighing 1,000g (1kg) or more and 'small' bars weighing less than 1,000g.

The purity or gold content of the bars is usually marked on the bar in parts per 100, 1,000 or 10,000 as follows:

- 99.99 99.99 parts gold per 100;
- 999.9 999.9 parts gold per 1,000; or
- 9,999.9 9,999.9 part gold per 10,000.

Cast bars include 400oz bars, kilobars, 100g bars, 10 and 5 tola bars and 10 and 5 tael bars¹⁷.

Historically, the two primary refineries made significant sales of 10 tola bars and 5 tola bars. The 10 tola bar was widely traded in India, Pakistan and the Gulf. However in 2003, the Indian authorities changed the local tax regime which halted demand for the tola bars. Specifically, they centralised the VAT system in India which meant that the tola bar became subject to VAT. Indian consumers ceased buying the tola bar and switched to 100g bars and kilobars which were not subject to VAT. Both primary refiners in South Africa adjusted their manufacturing emphasis to meet this shift in Indian consumer preferences.

As a consequence, sales of gold bars from South Africa in 2004 were predominantly kilobars (51%) and 400oz bars (46%). In 2004, the two primary refiners reported no sales of tael bars or minted bars.

Analysis of South African gold bar sales 2004

Cast bars	t	%
400oz bars:		
99.9 London Good Delivery	4.5	1.05
99.5 London Good Delivery	193.7	44.77
Sub-total	198.2	45.81
Kilobars:		
99.9	83.6	19.32
99.5	138.0	31.90
Sub-total	221.6	51.22
500g bars 99.5		
100g bars 99.9	0.3	0.08
10 Tola bars	12.0	2.77
Sub-total	0.5	0.12
Sub-total	12.8	2.97
Total	432.7	100.00

Data Source: Rand Refinery Limited and Musuku Beneficiation Systems

Cast bars

In South Africa, only Rand Refinery and Musuku cast gold bars and, of the two, Rand Refinery has the widest product range. The dimensions and specifications of Rand Refinery's cast bars are detailed in the table below and are typical of similar bars fabricated elsewhere by other international refiners. Musuku's product line includes kilobars and 100g bars of the same dimensions and specifications as those cast by Rand Refinery.

¹⁶ Purity, weight, serial number and refiner's mark; see later for further details.

¹⁷ Tola is an Indian unit of weight: 1 tola = 0.375 oz or 11.664g. Tael is a Chinese unit of weight: 1 tael = 1,203oz or 37,429g.

Five weights of cast bars, namely 400oz bars, kilobars, 100g bars, 500g bars and tola bars, are fabricated by the primary refiners.

400oz bars are cast and, to be accepted as London Good Delivery, they must conform to the following specifications:¹⁸

- the fine gold content must fall within a range of 350oz and 430oz (10.9 to 13.4 kg);
- bar purity must not be less than 995 parts gold per 1,000;
- bars must bear the marks of the refiner/assayer, the fineness of the gold content and a serial number unique to the bar; and
- bars must be smooth, free from surface cavities and bubbles. They must also have rounded edges and must be easy to stack and handle.

The kilobar is the world's most widely manufactured and traded gold bar, being globally the most widely recognised and accepted. They are cast in three purities 999.9, 999 and 995 parts gold per 1,000 purity.

The Rand Refinery kilobar specifications are shown in the table below. Musuku also produce kilobars in 995, 999 and 999.9 parts gold per 1,000.

The 100g bars and, to a lesser degree, 500g bars, have become increasingly popular in India, particularly since changes in VAT legislation. Musuku produces 100g bars in 995, 999 and 999.9 parts gold per 1,000.

Tola bars are still fabricated by Rand Refinery in 10 and 5 tola weights, although following the changes in the Indian VAT structure, demand for these bars has declined.

Rand Refinery cast bars

	400oz
Purity	min 995 or 999.9
Dimensions (mm)	
Top	260 X 80 X 40
Base	240 X 60 X 40
Serial numbers	2 letters, 4 numbers
1st Year of current shape	1921
	Kilobar
Purity	min 995 or 999.9
Dimensions (mm)	116 X 51.5 X 9.5
Serial numbers	2 letters, 4 numbers
1st Year of current shape	1959
	100g bar
Purity	999.0
Dimensions (mm)	45 X 27 X 4
Serial numbers	As required
	10 Tola bar
Purity	999.0
Dimensions (mm)	45 X 27 X 5
Serial numbers	None
	5 Tola bar
Purity	999.0
Dimensions (mm)	31 X 19 X 4
Serial numbers	None
	10 Tael bar
Purity	999.0
Dimensions (mm)	89 X 40 X 6
Serial numbers	None
	5 Tael bar
Purity	999.0
Dimensions (mm)	70 X 29 X 5
Serial numbers	None

Data source: Rand Refinery Limited and The Industry Catalogue of Gold Bars Worldwide, Grendon International Research, 1998.

Quotable quotes:

"There is no money to be made in small bars, so you have to go for volume. Your only chance to achieve a reasonable margin is in the semi-fabricated products, but here your market is limited to the local environs which we believe is capped by the prohibition on owning unwrought gold and the imposition of value added tax."

Major refiner

The kilobar is the world's most widely manufactured and traded gold bar...

¹⁸ LBMA good delivery specifications: <http://www.lbma.org.uk>.

CHAPTER 3

DORÉ TO SEMI-FINISHED PRODUCT: REFINING AND RECYCLING

The two primary refiners offer a wide range of gold products for jewellery manufacture...

Rand Refinery manufactures coin blanks for the striking of Krugerrands...

The financial aspects of the local and international refining industries have always been confidential...

Minted Bars

The three most common minted bars are 10, 50 and 100g bars. Rand Refinery first began minting these bars in 1999, in 999.9 parts gold per 1,000. While these bars are available, no sales were recorded in 2004.

3.6.2 Jewellery products

The two primary refiners produce a range of gold products for jewellery manufacture. These products are in the form of grain, sheet, wire, foil, strip and plate of various alloys termed semi-finished products or semis. Jewellery manufacturers purchase these products depending on their manufacturing process.

The two primary refiners offer a wide range of these products in different caratages and colours. As an example, the range of grain offered by Rand Refinery is demonstrated in the table below:

Rand Refinery jewellery alloy

Alloy grain	Code	Colour	Melting Range* C	Hardness	Applications
9 Carat	09DD	Yellow	900 - 950	Semi-Soft	Casting
9 Carat	09J	Yellow	880 - 960	Medium	General purpose
9 Carat	090A5	Yellow	980 - 1,000	Medium	Casting
9 Carat	09CW	Medium white	980 - 1,050	Medium	Casting, 2% Nickel
9 Carat	09LX	White	950 - 1,000	Semi-Soft	Casting
9 Carat	09RJ	Rose	960 - 1,000	Medium	General
14 Carat	14J	Yellow	935 - 980	Medium	General purpose
14 Carat	14LX	White	980 - 1,020	Semi-Soft	Casting
14 Carat	14RJ	Rose	960 - 1,000	Medium	General
18 Carat	18J	Yellow	930 - 980	Medium	General purpose
18 Carat	18D	Yellow	970 - 1,000	Semi-Soft	Casting
18 Carat	18SW	Soft white	1,100 - 1,250	Soft	Casting, 17% Pd
22 Carat	22J	Yellow	950 - 980	Medium	General purpose

Data source: Rand Refinery Limited.

Grain is widely used by jewellery manufacturers since it can be bought in small quantities and is applied to casting techniques. Strip and sheet is applied to stamping, and wire for chain-making.

3.6.3 Coin blanks

Coin blanks are manufactured solely by Rand Refinery for the striking of Krugerrands. (See Chapter 5 for further information).

3.6.4 Dental alloys

The primary refiners also produce a range of dental alloys. (See Chapter 5 for further information).

3.7 FINANCIAL PERFORMANCE

The financial performance of both the local and international refining industries is not made public and information is difficult to obtain. This section attempts to shed light on the operating cost structure of the two primary refiners and the recyclers, on the refining terms quoted to clients and on mark-ups applied to their respective products.



3.7.1 Ownership of gold during the refining process

Ownership of gold in the refining pipeline is typically as follows:

- refining contracts are entered into between refineries and mining clients in which treatment terms are agreed;
- doré is weighed and assayed at the mine, and the refinery is notified of the quantity of doré to be delivered and its estimated fine gold content;
- the mining client's account is credited with the value of the anticipated volume of metal contained. Payment terms vary but payment to the mining customer is generally not cleared until doré has physically been delivered to the refinery;
- the refinery concludes sales to buyers on the basis of the anticipated volume of gold to be delivered;
- the gold price applied to the refinery's sales of gold to end users is the same as that used to pay the mining client so that the refinery takes no exposure to the gold price. Usually the fix on the day of delivery of gold to the refinery is used as a basis for pricing;
- the gold is again assayed by the refinery, and any differential between the original anticipated metal content and the final assay is settled in value terms between the refiner and the mining client; and
- the refined gold is then sent to buyers directly from the refinery or according to the buyer's specific instructions.

At no stage during this process does the refinery take ownership of the gold being refined.

3.7.2 Operating costs

The research was able to highlight certain similarities in the cost structures of Rand Refinery and Musuku, as follows:

- labour costs for both companies are approximately 42% of total operating costs;
- raw materials (for example chemicals), represent the second largest cost at 24% of the total; and
- energy and marketing account for approximately another 5% and 4% respectively.

The remaining components of total operating costs include waste disposal, security and other overheads.

For the recyclers, the weighted average cost breakdown varies as follows:

Typical cost profile: recyclers	%
Raw materials	7.5
Waste disposal	2.5
Insurance	2.5
Labour	42.4
Rent	10.4
Energy	10.8
Marketing	15.9
Other overheads	8.0
Total	100.0

Data source: Interviews.

At no stage during the process does the refinery take ownership of the gold being refined...

Labour costs for both companies are similar, representing 42% of total operating costs...

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DORÉ TO SEMI-FINISHED PRODUCT: REFINING AND RECYCLING

Labour remains the major cost for both primary refiners and recyclers...

Primary refiners and secondary recyclers will vary treatment terms to gain or maintain a competitive advantage...

Treatment terms are highly confidential...

With respect to these costs, it is worth noting the following:

- labour at 42% of the total remains the major cost for both the primary refiners and the recyclers;
- for the recyclers, marketing is a relatively high cost (at almost 16% of the total) but this includes the cost of sales representatives servicing the regional manufacturing and retail jewellers;
- energy (both gas and electricity) makes up just over 10% of costs for the recyclers while for the primary refiners it represents a smaller 5%; and
- waste disposal is a fixed cost imposed by environmental legislation. It involves gaseous emission controls from the refinery and safe disposal of chemical waste generated in the refining process.

3.7.3 Treatment terms

The cost and conditions of refining gold quoted by the refiners are referred to as the treatment terms. In an international industry with surplus capacity, primary gold refiners and secondary recyclers will vary their treatment terms in order to gain an advantage. There is therefore no strict formula to which a refiner or recycler will conform when drawing up refining terms. This section describes industry norms in principle, but highlights where treatment terms can vary between the refiners and recyclers.

Depending on the circumstances described below, international gold refining treatment charges applied to kilobars and other small bars range between 30-45 US cents per ounce with 100% metal returned. Within this range, treatment terms are around 0.1% over the spot price of gold.

The terms described above are general and individual agreements will vary depending on:

- costs incurred as a result of currency fluctuations should the physical location of the refinery and the customer be in different currency areas;
- the particular content of the feed and the ratio of gold to other precious metals in the feed. Other precious metals such as silver and PGMs in the feed will be recovered and the customer is paid for these metals, termed by-product credits;
- the existence of deleterious elements such as mercury, lead and beryllium in the feed. These elements have to be removed during the refining process and the refiner will charge to do this;
- the existing relationship with the customer;
- the volume of feed;
- the regularity of feed; and
- transportation distances and methods of transport between the client and the refinery.

Treatment terms quoted by primary refiners in South Africa to customers are considered highly confidential. In general, however, terms are broadly in line with those cited as average for the international refining industry.

In South Africa, the treatment terms for scrap vary considerably between the recyclers and their customers, and the various categories of scrap¹⁹.

Research shows that:

- for high grade scrap (old jewellery in any caratage), customers receive 95% of fine gold recycled in volume terms, or a simple payout on the assay and calculated fine gold content based on Rand Refinery prices of the day²⁰;
- for jewellery sweepings, the refinery will return 85-92% of fine gold content in either metal or value at the Rand Refinery price of the day, subject to a minimum refining charge of R900 per job lot irrespective of the size of the job; and
- for washings²¹, the refiner will return 85%-90% of fine gold content, or the value of that amount of fine gold based on the Rand Refinery prices of the day.

¹⁹ These are defined in more detail in the next section.

²⁰ The Rand Refinery price is discussed in more detail later in this chapter.

²¹ Washings are the liquid waste resulting from the cleaning of jewellery during fabrication. This waste contains flecks of gold and is routinely recycled.



Where a recycler is aggressively bidding for scrap, the recycler will discount the treatment charges for targeted customers, returning anything from 97-99.5% of the contained fine gold or the value of that gold (in Rands). In these instances, the companies interviewed acknowledged that this business practice was a loss leader for the company but was implemented where the operation needed feed material.

3.7.4 The Rand Refinery price of gold

The Rand Refinery quotes Rand-denominated prices for its gold products to its local customers. This price is set twice-daily and is available on request. Given that the price is used widely by recyclers as a benchmark by which they calculate their own prices to customers, a description of the price mechanism is included:

- on any business day until noon local time, Rand Refinery will use the afternoon London gold price fix of the previous day and the Rand/Dollar exchange rate at the closing of the previous day;
- after midday on any business day, Rand Refinery will use the morning London gold price fix of that day and the noon Rand/Dollar exchange rate of the same day; and
- if, for whatever reason, there is no London morning or afternoon price fix, (usually in the case of bank holidays in the United Kingdom), the Rand Refinery will use the most recent London price fix.

3.7.5 Mark-ups

Mark-ups over the gold price achieved by the primary refiners in South Africa for kilobars and other small bars are low, in keeping with premia achieved for small bars internationally. 30 to 45 US cents per ounce is standard for kilobars. 100g bars and other smaller bars may command slightly higher mark-ups. Mark-ups achieved will vary according to international demand for small bars, but not necessarily according to the gold price.

With respect to other gold products associated with the jewellery manufacturing industry, mark-ups are higher, but vary depending on:

- the size of a purchase: the smaller the order, the higher the mark-up;
- the content of the alloy: alloys containing palladium and platinum command higher mark-ups than those containing copper and silver;
- the relationship between the customer and the refiner: the longer and more trusted the business relationship, the greater the possibility of discounts; and
- the frequency of purchase.

Research among recyclers indicated the following as examples of mark-ups (over fine gold content) on different products for the jewellery manufacturing sector. It should be noted that these mark-ups are benchmarked to the daily quoted Rand Refinery price for fine gold:

- 6% and up for low carat (9 carats to 14 carats) solders and findings such as earrings, wings and clasps;
- 4% and up for high carat solders and findings (18 carats and above); and
- 36% and up for dental alloy depending on the PGM content.

The range of mark-ups over the fine gold content is presented in the following table:

Typical price mark-ups for gold alloys by recyclers

	%
22 carat yellow and red	4
18 carat yellow, red and white	6
18 carat with palladium	16
18 carat with platinum and palladium	36
14 carat red and yellow	6
14 carat white	25
9 carat yellow and red	6
9 carat white	38

Data source: Interviews.

Rand Refinery sets the price twice-daily for its gold products...

Secondary recyclers use the Rand Refinery price of gold as a benchmark...

Mark-ups achieved by primary refiners for kilobars are low, at between 30 and 45 US cents per ounce of gold...

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Quotable quotes:

"Jewellery sweepings are disgusting. We get these dustbin bags bursting at the seams with anything from six-month old sandwiches to cold drink cans. With all this rubbish, jewellery manufacturers then complain that the recovery grade is so low. Occasionally I refuse to handle the stuff and have sent it back."

Recycler

Some seasonality exists in the rate at which jewellery scrap and waste is returned for recycling...

There is no formal hallmarking system in place in South Africa...

A number of jewellery manufacturers mark their jewellery...

3.8 RECYCLING FEED

Those businesses involved in the treatment of recycled gold, including the primary refiners, take secondary feed for recycling from a number of sources.

These sources include:

- old jewellery traded in for upgrading or refashioning from the private sector, or job lots of unsold jewellery from major retailers after a stock clear-out²². In line with the predominant gold caratage of finished jewellery product in South Africa, 95% of this material is 9 carat;
- jewellery fabricating or process scrap generated during the manufacture of gold jewellery, including filings and polishings, offcuts and rejects. While 95% of this scrap is 9 carat, it can also contain 14 carat and 18 carat scrap. Jewellers' process scrap is usually returned by the jewellery manufacturers to the refiners on a monthly basis to assist the manufacturers in managing cash flows. The level of process scrap is relatively large, up to 40% of the volume of gold used by jewellery manufacturers;
- jewellery sweepings, literally the floor sweepings of jewellery workshops collected and sent in, usually bi-annually, for recycling include material other than precious metals, and the gold content is low (varying between 0.5% to 2% in weight). Under exceptional circumstances, a good sweep can contain 30g of fine gold per kilogram of sweeping, but these instances are rare;
- wash waters from the jewellery manufacturing process which can contain 4% to 5% gold (in weight);
- medical waste, primarily from x-ray films which contain silver;
- dental alloy, which is regularly returned for recycling. This is because there is a high degree of wastage in this application²³. To apply a gold filling, a dentist only uses up to 25% of the metal he needs to work with; the balance is immediately recycled; and
- electronic waste which has been increasing in recent years and which includes not only gold but also palladium and silver. Not all the refiners and secondary recyclers can process electronic scrap. According to interviews, Rand Refinery, treats between 6t and 10t of electronic scrap annually. The precious metals content of this feed can vary, but on average the material currently being returned for recycling can typically contain 200g/t of gold.

There is some seasonality in the rate at which jewellery scrap and waste is returned for recycling which is not sensitive to international or local gold prices. This waste is returned with the greatest frequency and in the largest volume during the period just before Christmas. There are two reasons for this:

- this is when manufacturers are busiest and are generating the maximum in process scrap; and
- it is during this period that financial pressures on manufacturers are greatest due to demand for working capital.

3.9 ASSAYING

There is no formal hallmarking system in place in South Africa and this has been cited as a deterrent to locally made gold jewellery gaining international recognition and acceptance.

However, a number of jewellery manufacturers do mark their jewellery with either a caratage stamp or a manufacturer's insignia. Furthermore, recyclers such as First Assay offer assaying facilities in addition to those offered by Rand Refinery.

Interviews with those companies offering assay services revealed the following costs and associated terms:

- six hours for results of an assay. If urgently required, an assay can be done in 2 1/2 hours at an additional cost to the client;
- typically R65 per assay to yield gold and silver results;
- certificates are issued on all assays; and
- doré assays, mainly on behalf of smaller mining companies, are included in the treatment terms ranging from 2% to 5% of the fine gold content.

²² Retailers' policies on sending unsold finished jewellery back to the refiners is discussed in more detail in Chapter 4.

²³ See Chapter 5 for details.



Discussions with those regularly involved with assaying indicate that there is under-carating in the South African gold jewellery industry. It was claimed that this was often unintentional with inexperienced jewellers producing their own alloys. At other times, however, this under-carating appears to be deliberate and the large retailers make a practice of having all their stock assayed prior to it going into shop windows.

3.10 BARRIERS TO MARKET ENTRY

The continuing global state of over-capacity in gold refining represents the foremost barrier to market entry for potential newcomers to the refining industry, with current capacity utilisation at 55% (although this varies on a regional basis).

The decision to commission the Musuku refinery in 1997 was not based on the need for further refining capacity in South Africa or indeed globally, but on Harmony's own marketing and process imperatives. The newly-commissioned refineries in Dubai, with the latest technology²⁴, have added to global refining over-capacity and placed additional pressure on the industry.

To win refining contracts, individual operations not only have to be very competitive, but also concentrate on additional logistical options. These include offering potential clients a one-stop service from the mine gate including airfreight and insurance.

3.11 REFINING TECHNOLOGY

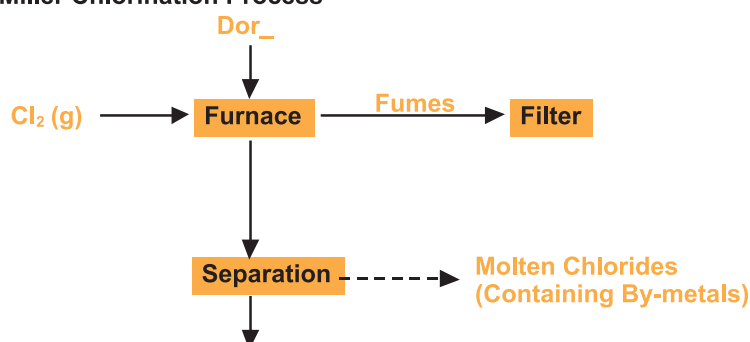
Two refining processes are currently in use in South Africa. Rand Refinery makes use of the Miller Chlorination Process and Wohlwill electrolysis. Musuku Beneficiation Systems makes use of the Minataur Process. Both these processes are described very briefly below and flow charts of both processes are included.

3.11.1 The Miller Chlorination Process and Wohlwill Electrolysis

The Miller Chlorination Process was first developed by Dr F. B. Miller at the Sydney Mint and is widely used internationally in the large-scale refining of gold.

It is a pyrometallurgical process whereby gold doré is heated in furnace crucibles. The process is able to separate gold from impurities by using chlorine gas, which is added to the crucibles once the gold is molten. Chlorine gas does not react with gold, but will combine with silver and base metals to form chlorides. Once the chlorides have formed, they float to the surface as slag or escape as volatile gases. The surface melt and the fumes containing impurities are collected and further refined to extract the gold and silver.

Miller Chlorination Process



Source: Dr.W.S. Rapson, 'Gold Refining Methods,' Gold Refiners & Bars Worldwide. 1991. The Gold Institute

Indications are that there is under-carating in the South African gold jewellery industry...

The continuing over-capacity represents the foremost barrier to market entry for potential newcomers...

To win refining contracts, refineries now look at logistics...

Two refining processes currently used in South Africa...

²⁴ See earlier in the chapter for details.

CHAPTER 3

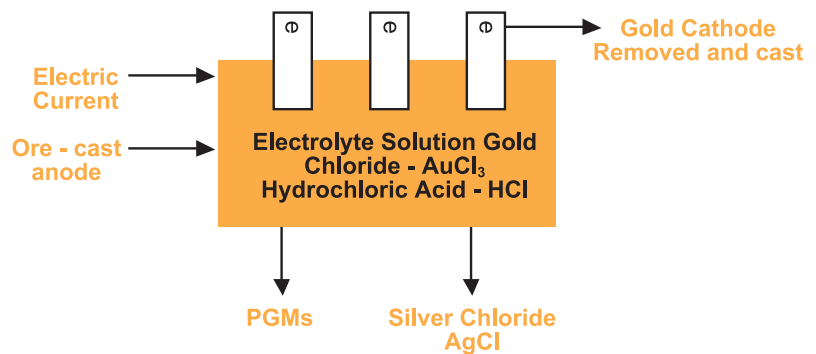
DORÉ TO SEMI-FINISHED PRODUCT: REFINING AND RECYCLING

The Miller Chlorination Process, which can take up to 90 minutes, produces gold that is at least 99.5% pure, with silver being the main remaining component. This gold can be cast into bars, as 99.5% gold purity meets the minimum 'London Good Delivery' requirements of the London bullion markets.

However, some customers such as jewellers and other industrial end users require gold that is almost 100% pure, so further refining is necessary. In this case, gold using the Miller process is cast into anodes, which are then sent to an electrolytic plant. The final product is a 99.99% pure gold sponge that can then be melted to produce various end products suited to the needs of customers.

The electrolytic method of gold refining was first developed by Dr. Emil Wohlwill in 1874. Wohlwill's process is widely used in major gold refineries and in conjunction with the Miller Chlorination process. The Wohlwill process is based on the solubility of gold and insolubility of silver in an electrolyte solution of gold chloride in hydrochloric acid.

Wohlwill Process



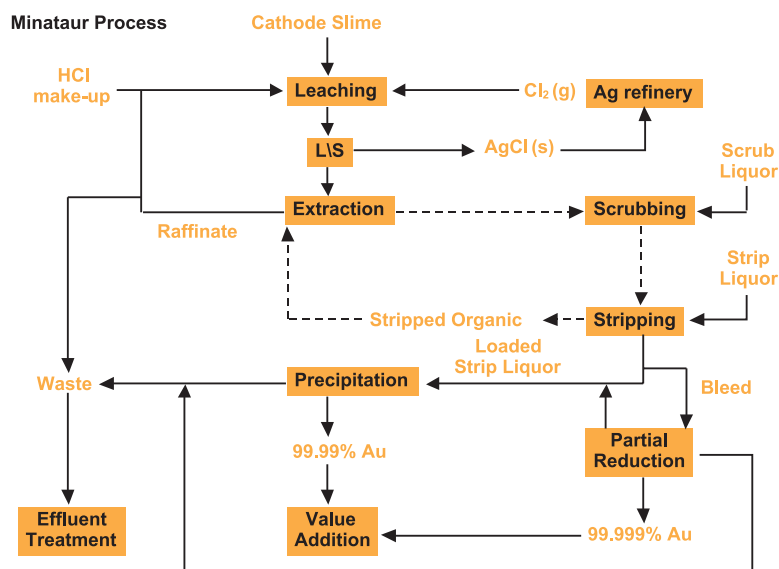
Source: http://www.pamp.com/gold_c/Info_site/in_glos/in_glos_wohllill.html

The impure gold is cast into anodes which are suspended in cells, while the cathodes are thin strips of pure gold. By passing an electric current from anode to cathode through the electrolyte solution, the anodes are gradually dissolved and the gold is deposited on the cathodes; any silver, which is insoluble in the electrolyte, and any platinum group metals are precipitated to the bottom of the cells. The sequence takes about two days, following which the gold-coated cathodes are removed, melted and cast into bars. The initial process can produce gold up to 999.5 parts per thousand fine, with further treatment bringing it up to 999.9 parts per thousand.

The disadvantage of the Wohlwill process is that it is time consuming. Consequently, most gold is refined using the quicker Miller Chlorination Process, which can take gold to 995 parts per thousand fineness. Where gold of 999 or 999.9 parts per thousand is required, electrolytic facilities at many refineries have been added.

3.11.2 The Minataur Process

The Minataur Process was developed by Mintek. In this process the gold-bearing feed is leached in a chloride solution. The resultant material is then subjected to selective solvent extraction to reject impurities and then stripped to produce a purified, concentrated gold solution, from which high-purity gold powder is precipitated by reduction.



Source: <http://www.musuku.com/minataur/flow2.htm>

The gold content of the feed can range from about 20% to 90%. Suitable feeds include silver-refining anode slimes, gold-electrowinning cathode sludge, zinc precipitation filtrates, doré bullion and jewellery scrap. Materials with variable gold content can be handled.

The Minataur Process allows miners to refine their own high-purity gold on site. The refined product is formed into 99.99 percent or higher purity gold granules.

The first Minataur plant was constructed in 1997 for Harmony in Virginia, in the Free State. This plant has been expanded, and now processes all of Harmony's gold output from its South African operations. Subsequently, turnkey plants have been built and supplied to customers in Mexico, the United Arab Emirates and Algeria. The plant in the United Arab Emirates is the largest of these with capacity up to 150t per annum. Plants in Algeria and Mexico are small, with a capacity of 1t to 3t per annum.

3.12 ENVIRONMENTAL ISSUES

The refining and recycling industries have two areas of environmental control that apply specifically to their operations. The first is the appropriate disposal of waste products (for example chemical residues) generated during the refining process and the second is atmospheric emission and air quality control. These environmental regulations apply to all the refining and recycling operations in South Africa irrespective of their locations.

International environmental management standards under the International Standards Organisation (ISO) can also be applied to the gold refining industry. The ISO is a network of national standards institutes in 153 countries on the basis of one member per country. The Central Secretariat is based in Geneva and the South African member of the ISO is the South African Bureau of Standards (SABS). The ISO standard relating to the environment is ISO 14001.

Rand Refinery achieved ISO 14001 certification in April 2001.

The first Minataur plant was constructed for Harmony in Virginia, in 1997...