

Change from top-blown to bottom-blown converter for lead bullion cupellation at Rand Refinery

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Synopsis

In 1986, Rand Refinery rebuilt its smelter plant, which recovers gold and silver from gold mine by-products, to incorporate arc furnace lead smelting and cupellation of the lead bullion in a top-blown rotary converter (T.B.R.C.). Whilst the new process realised important improvements over the old blast furnace/cupel furnace route, the operation of the T.B.R.C.'s has proved difficult and the problem of frequent refractory failure has never been satisfactorily overcome.

During 1993, management reviewed the strategic requirements of the smelter plant and the Board approved a further upgrade project to address various shortcomings, including the difficulties with the T.B.R.C.'s. The total project cost was R10.5 million of which approximately 25% related to for the installation of a 4 ton capacity bottom-blown oxygen converter (B.B.O.C.) and ancillaries to replace the two 1.5 ton T.B.R.C.'s. The reason for the change in cupellation technology, the alternative technologies and processes investigated and the overall operating improvements achieved by the B.B.O.C. are discussed.

1 Introduction

Since the new smelter circuit was commissioned in September 1986, all arc furnace lead bullion production has been processed through two 1.5 ton capacity T.B.R.C.'s and a small static reverberatory cupellation furnace in order to produce doré bullion containing gold and silver. The design and basic operating data for the TBRC's at Rand Refinery is given in reference (1).

The original concept was to produce doré bullion directly from the T.B.R.C.'s, but this proved impossible as it was found to be very difficult to take the oxidation stage to completion and also maintain the temperatures at which doré bullion would remain molten. This necessitated a compromise process whereby the arc furnace lead bullion was concentrated (i.e. approximately 75% of the lead is oxidised) in the T.B.R.C., but the remaining relatively small amount of high-grade bullion was transferred to a reverberatory cupel furnace for final oxidation to doré bullion. Other process difficulties encountered with the operation of the T.B.R.C.'s included the following:

- i) difficult fume containment when pouring products;
- ii) difficult temperature control, especially as lead concentration decreases and reaction end-point is approached;
- iii) no means of holding temperature in the converter whilst pouring final doré bullion;
- iv) relatively low oxygen efficiency (approx. 30%);

- v) high maintenance requirements (roller bearings etc.) in addition to frequent furnace shell removal for refractory repairs or relines;
- vi) refractory failures caused by a varying combination of overheating; erosion; spalling, lead penetration through brick joints, and inconsistent refractory quality; and
- vii) the necessity to finish the oxidation in the traditional cupel furnace (arising from points ii and iii above), which also introduced further difficulties especially in terms of fume containment and operator health problems, metallurgical losses and security of precious metal.

In January 1993, a Smelter Project Steering Committee was formed with a brief to investigate alternative technologies to replace the T.B.R.C./cupel circuit. The committee agreed that when considering "what would be the most suitable technology for our particular process", it was important that the following criteria were satisfied:

- process **must** be able to produce doré bullion from arc furnace lead bullion in a one stage operation, so eliminating the traditional cupel furnace;
- operation and control must be easy;
- the process must achieve low-maintenance, low-cost and give improved refractory life;
- good hygiene is essential (i.e. negligible lead fume emitted during all phases of operation);
- the process must give improved metallurgical accounting and security; and
- the equipment must have sufficient processing capacity to treat all arc furnace lead bullion arisings and be capable of catching up on any backlog, should it occur.

A number of alternative processes to the T.B.R.C.'s were examined and eventually three were considered for investigation in detail. These were:

- conversion of the T.B.R.C. combined lance/burner arrangement to an "Outokumpu" separate lance burner configuration;
- submerged lance smelting (as initially developed by the Australian CSIRO); and
- bottom-blown oxygen injection.

These options are discussed further.

2 Investigation Of Alternatives Processes

2.1 *Modifying Existing TBRC's*

Applicaton of the "Outokumpu" lance conversion to existing TBRC equipment was thought to offer the following advantages:

- uses the existing T.B.R.C. body, rotational and tilting mechanisms;

- only the burner/lance arrangement and existing off-gas hood need be changed;
- lower capital costs than the other processes being considered;
- installation of new lance/burner and off-gas hood arrangement would be far quicker than the installation of a completely new process; and
- less disruption to normal arc furnace production due to the relatively short duration of the conversion.

Detailed investigations showed that for Rand Refinery's particular application, its T.B.R.C. must have the correct auxiliary equipment to make it competitive with bottom-blown technology. This was not the case with the existing T.B.R.C.'s and the Smelter Project Steering Committee considered the option of changing the existing combined burner/oxygen lance with a lance beam with two separate lances (i.e. one burner and one refining lance). Therefore the following modifications were proposed:

- Up-rate the burner to 2MW capacity and adapting it to work with the refining lance.
- Introduce a refining lance with a well designed high pressure, supersonic nozzle. Normal operation is with compressed air ($15\text{Nm}^3/\text{minute}$ @ 3 bar minimum), but the addition of oxygen would also be possible.
- Redesign the process off-gas system so that all cooling (false) air is introduced in the gap between the furnace mouth and hood, thereby cooling the off-gases to less than 200°C . An estimated total off-gas volume of $10000\text{Nm}^3/\text{h}$ would need to be handled.

These modifications would produce the following benefits:

- The increased burner capacity would shorten the melting period, but also make it possible to charge more cold materials directly to the T.B.R.C.
- High pressure top blowing is many times more effective than the existing system and is able to penetrate thick layers of slag without a high rotation speed. The resulting high oxygen efficiency would give good temperature control and a shorter process cycle time.

It was also proposed that other direct changes be made to the T.B.R.C. operations. It is thought that the high level of very liquid PbO-slag on top of the bullion reduces the oxygen efficiency during oxidation. To prevent this de-slagging would be necessary to significantly reduce the bath volume after two thirds of the refining period. Fluxes would then be added that collect PbO and form a lump slag phase which leaves areas of high grade bullion open to the furnace environment. This would prevent the PbO from being "over oxidised" into higher oxides due to the decrease in Pb activity in the remaining high grade bullion. The combination of high pressure blowing together with a small amount of additives should make it possible to go directly to a <2% Pb bullion. It should also shorten the cycle time by >50% and make it possible to slow down the T.B.R.C.'s rotation speed, which should then increase the refractory life.

2.2 Submerged Lance Smelting

Submerged lance technology designed by Ausmelt for the cupellation of lead bullion containing silver has been in operation at Pasminco Metals - BHAS, Port Pirie, Australia for over 4 years, producing silver doré metal of at least 98.5% purity (2).

A visit was made to Port Pirie in May 1993, to observe the operations of the cupellation operations at BHAS. During the visit, detailed discussions with the furnace manufacturers and BHAS management indicated that the submerged lance smelting applied to Rand Refinery's particular cupellation process could offer the following advantages;

- production of doré bullion up to 98.5% purity from Ag-Au lead bullion;
- high oxygen efficiency (approaching 100%) and use of compressed air instead of oxygen;
- best claimed refractory life of all three processes investigated (± 24 weeks), based on 8 hours/day operation;
- process 5 tons of arc furnace lead bullion per day on a day shift only operation;
- furnace will easily be accommodated in existing arc furnace building;
- good furnace hygiene if tapping hoods are designed correctly; and
- use of the process for other applications (i.e. both oxidation and reduction processes).

Subsequent to the visit to BHAS at Port Pirie, a basic plant and process description was formulated as follows.

The proposed process involved tapping lead bullion from the submerged arc furnace twice a day, at approximately 2.5 tons per tap. Depending on the availability of the submerged lance furnace, the bullion would be fed directly in the molten form, or granulated for use later in the shift should the furnace be unavailable.

The lead bullion would assay approximately 1% Au and 3% Ag. There would be some contamination of the lead bullion with matte. This was thought unlikely to significantly affect the operations of the furnace as the oxidising conditions prevalent in the cupellation furnace would result in the components of the matte being oxidised to slag.

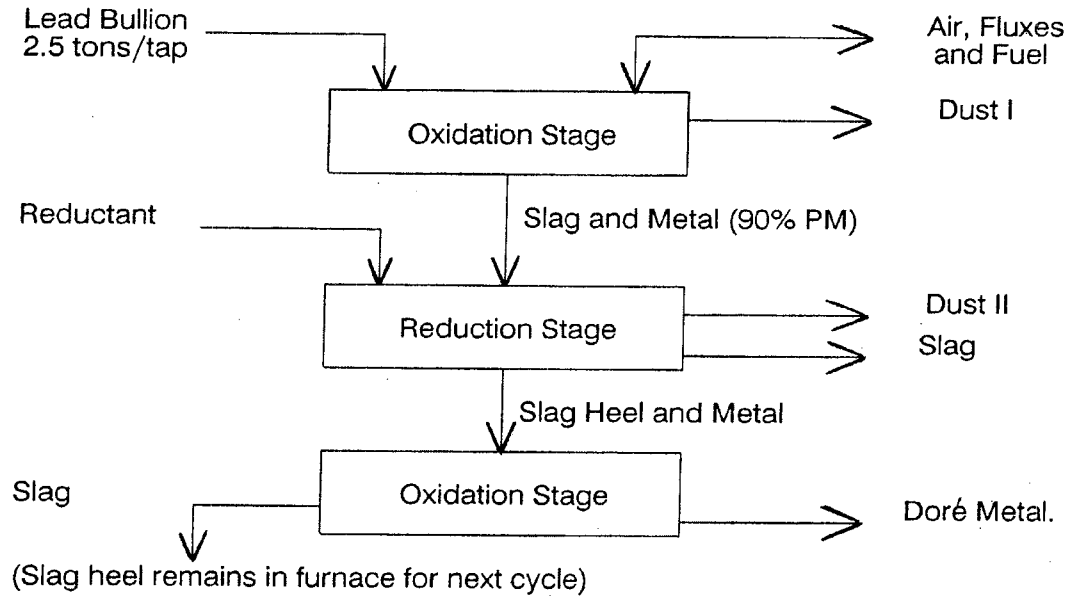
It was proposed that the furnace would have an internal diameter of approximately 1.2m and a height of 2.5m. The furnace would be fitted with a water-jacketed steel shell and have high quality chrome-magnesite bricks as the refractory lining.

The top submerged lance system would provide for combustion and oxidation of the bath under turbulent conditions, giving efficient heat and mass transfer for the melting and oxidation operations. The lance design would promote good metal/gas contact, maximising reaction rates and stirring the bath without the need for external mechanisms, so providing the operation with a high specific

smelting rate. The lance would be lowered, raised and replaced by use of a simple lance hoist and jib assembly, the lance entry port being located in the furnace top. The process engineering of submerged lance reactors and the lance and bath-mixing characteristics are well documented, in reference (3).

The proposed process flowsheet for a single furnace operation is shown in figure 1 below:

Figure 1 Proposed Process Flowsheet



It was proposed that at the start of each cycle, the furnace would contain a small amount of bullion (approximately 50-100 kg) and approximately 400 kg of lead oxide (litharge) slag.

The metal taphole would be located in the furnace bottom and the slag taphole on the opposite side at a height sufficient to provide 500 kg doré bullion capacity, ensuring that at the end of a cycle during tapping, the metal level was below the slag taphole.

Approximately 2.5 tons of molten arc furnace lead bullion would be added to the furnace using a crane supported ladle, through a feed port in the furnace roof. The bath would then be heated to approximately 1000°C during the initial oxidation stage. The lead bullion would be oxidised to produce metal containing approximately 90% precious metals. Once this level was achieved, the slag would be rapidly reduced by the addition of lump coal and the furnace slag allowed to settle before tapping and granulation.

The remaining alloy would then be further oxidised to doré metal. The final doré grade would be determined by visual inspection of metal samples taken by the operators. When doré containing 2% Pb and Cu was achieved, the remaining slag would be tapped and granulated, and the doré would then be tapped into moulds.

The slag and fume products would be recycled to Rand Refinery's existing operations for lead recovery.

2.3 *Bottom-Blown Oxygen Injection*

This particular furnace technology has been investigated by management at Rand Refinery since 1990, (4)(5)(6). In May 1993 a visit was arranged through MIM Technology Marketing Ltd (MIMTM) to view the operations of their 3 ton capacity Bottom Blown Oxygen Converter (BBOC) at Britannia Refined Metals Limited in Northfleet, Kent.

This BBOC has been operational at Britannia Metals for 8 years, and is used to remove both lead and copper from a 60-70% silver/lead alloy which has been through a vacuum retorting process. After this alloy is cupelled in the BBOC, a doré bullion running in excess of 99.85% silver is produced from the furnace.

Discussions with MIMTM indicated that Bottom-Blown Oxygen Injection, could offer the following advantages over the existing TBRC's at Rand Refinery:

- concentration and final cupellation of arc furnace lead bullion containing $\pm 3\%$ Ag and 1% Au in one operational step to produce a doré bullion >98.0% purity;
- very high thermal and oxygen efficiencies, with resulting cost savings;
- much reduced susceptibility to refractory problems i.e. (claimed refractory life approx. 14 weeks), based on 24 hour operation;
- ease of operating by staff with relatively low levels of skill;
- process is very simple to control as lance feed is automatic and the converter can be left unattended;
- reduction in labour requirements from one man to $\frac{1}{2}$ man per shift;
- low off gas volume and excellent furnace hygiene during all operations;
- high metal recovery rates, low values in litharge slag;
- can take both solid or molten charge;
- furnace would fit easily into existing arc furnace building;
- improved security as all tapping operations could be easily monitored.

Subsequent to our visit to Britannia Metals Limited, MIMTM drew up a proposal, which they offered to build, supply and commission a 4 ton capacity BBOC, which would process 5 tons per day of arc furnace lead bullion, to doré bullion. The modus operandi of the BBOC is discussed later in this paper.

2.4 *Comparison of cupellation technologies investigated*

To facilitate an educated and informed decision on the best and most appropriate technology to replace the TBRC's, a comparison chart Fig. 2, was drawn up listing all the various equipment and operating criteria, and comparing the data available from the investigations carried out on the three different furnace technologies.

Figure 2 Comparison of Equipment and Operating Criteria

	TBRC (WITH "OUTOKUMPU" LANCE CONVERSION)	BBOC	SUBMERGED LANCE SMELTING
Lance Operation	Comprises lance beam with two lances, i.e. one burner and one refining lance. Lance operates above molten bath as a high pressure supersonic nozzle.	A hydraulic drive assembly automatically feeds the lance into the furnace as wear takes place. Wear is sensed by temperature measured in the lance thermocouple. Converter is bottom blown.	Top submerged type. The requirement is that the lance must be submerged in the slag. Frequent adjustment of lance required during operation.
Lance Replacement	Water cooled refining lance which is retractable. Lance life indefinite if correctly used and maintained.	Consumable stainless steel lance which requires replacement every 15 hours. Lance change takes about 5 minutes.	Lance life is variable due to operating parameters, but averages 8 hours. Replacement lance takes 10 minutes to install.
Heat Source	Separate water cooled gas fired burner of about 2MW capacity, fully retractable from the furnace body.	Fully proportionating gas burner with control equipment. The burner is positioned in the furnace body.	The lance is the heat source and can use either oil, pulverised coal or gas. A separate high velocity gas burner is required when starting the furnace up from cold.
Injected Gases	Normal operation with compressed air (15Nm ³ per min @ 5 bar pressure) but addition of oxygen is also possible.	Uses pure oxygen for lance injection and nitrogen for lance cooling. Oxygen already available; would have to install nitrogen facility.	Normal operation is with compressed air (6.25Nm ³ /min @ 5 bar pressure), but addition of oxygen is also possible.
Combustion Efficiency	Burner only required during charge heat up. During oxidation cycle, reaction is exothermic and burner is left off.	Burner only required during charge heat up and doré bullion casting operations. During oxidation cycle, reaction is exothermic and the burner is left off.	Lance burner on all the time even during oxidation reactions. Wear of lance will also affect efficiency due to erosion of the outer stainless steel pipe near lance tip, which allows splash back and subsequent blockage.
Bath Temperature Control	Knowledge of operation of existing TBRC's, suggested that temperature control would not be easy.	Precise and easy to control due to burner on or off option and precise control of oxygen injection during oxidation stages.	Because this process is an intensified process, an excess of heat is generated, especially during oxidation. Heat is removed or absorbed by addition of inert materials, therefore control is not very precise.
Oxygen Efficiency	Should be better than approx.30% currently achieved, due to use of high pressure supersonic nozzle, which is able to more easily penetrate thick layers of slag.	High (approaching 100%) due to submerged injection of process gases direct in reaction zone.	High (approaching 100%), due to submerged injection of process gases

Figure 2 (Contd.)

	TBRC (WITH "OUTOKUMPU" LANCE CONVERSION)	BBOC	SUBMERGED LANCE SMELTING
Off-Gas Requirements	Low off-gas volume (approx. 10000m ³ /hour)	Low off-gas volume (approx. 7500m ³ /hour), due to relatively quiescent bath as pure oxygen only is used in the oxidation reaction.	Significant off-gas volume (approx. 40000 m ³ /hour), due to turbulent bath conditions, high intensity process characteristics and use of compressed air for oxidation (only 10% of volume used, 90% to off-gas).
Hygiene	Good during melting and oxidation stages. However, due to height of pour during pouring operations, it would be very difficult to maintain good furnace hygiene	Excellent as furnace is fully enclosed during both melting/oxidation and pouring operations. Because of close to lip pouring axis, good slag/metal separation and direct cast anodes are obtainable.	Generally good during melting and oxidation stages although potential problems could be encountered with the lance and feed ports in the furnace cap. Good hygiene extraction would also be required for all pouring operations.
Feed Preparation	Flexible - can take solid or liquid bullion from arc furnace. However, solid charge tends to damage the refractory lining due to loading at an inclined axis.	Flexible - can take solid or liquid bullion. Solid bullion can be loaded in 300kg blocks in the vertical position.	Investigating the possibility of using liquid charge. Solid charge must be granulated and dried to less than 3% moisture. Granulation problems will be encountered due to mixed lead matte phase in the arc furnace bullion.
Final Doré Purity	Claimed that the combination of high pressure blowing together with small amounts of additives will make it possible to go directly to 98% Ag/Au doré bullion.	The Britannia Metals Limited BBOC can produce doré bullion in excess of 99.5% Ag purity.	The Port Pirie operation can produce doré bullion of around 98.5% Ag purity.
Refractory Life	Because the rotation speed of the furnace can be significantly lowered during the oxidation stages, it is claimed that refractory life will be increased. However, no figures to support this claim are given. Current TBRC refractory life around 2 weeks.	Britannia Metals claim an average life of around 14 weeks. Wear normally concentrated around slag line, hence a full re-line is not necessary. Recommendation to have a fully lined spare shell which takes about 8 hours to change.	Claimed that a partial re-line will be necessary after about 24 weeks. Also recommendation to have a spare lined shell, which takes about 5 hours to change. The converter cap or roof is normally changed about every 12 weeks.
Manpower Requirements	One man per shift required to operate two TBRC's. However he is able to do other work in between pouring and melting/oxidation operations, as process can be left unattended, once in operation. These converters would be operated on a 7 day x 3 shift cycle.	It is claimed that only 1/2 man per shift is required as all operations pertaining to this furnace can be carried out by one man. On average one man spends only four hours per shift working on the furnace. During meltdown/oxidation cycles furnace is left unattended. This converter would be operated on a 7 day x 3 shift cycle.	Can be operated on a days only shift cycle, but requires two men to operate. Furnace cannot be left unattended as lance height requires constant adjustment for effective operation. This converter would be operated on a 7 day x 1 shift cycle.

Figure 2 (Contd.)

	TBRC (WITH "OUTOKUMPU" LANCE CONVERSION)	BBOC	SUBMERGED LANCE SMELTING
Spare Requirements	TBRC's are currently located in the arc furnace building. No major structural changes would be necessary.	Requires an overall area of 5m x 4m which could easily be accommodated next to No. 1 TBRC.	Requires an overall area of 4m x 4m which could be accommodated in the existing arc furnace building next to No. 1 TBRC.
Security	If this modification allows direct production of doré bullion from the TBRC, the security will be very much improved.	Very good, as cupellation of bullion is a single stage process. Doré bullion would only be tapped on day shift twice weekly under supervision.	Very good, as cupellation of bullion is a single stage process. Tapping of doré as per BBOC. Granulated arc furnace lead could be a potential security problem.
Relative Cost *Estimate	<p>Full "Outokumpu" lance conversion on both existing Tolltreck TBRC's which includes:</p> <p>2 x water cooled burner, 2MW in stainless steel 2 x water cooled refining lance with nozzle 2 x lance support system</p> <p>Relative cost was 62%* of total price for supply of BBOC.</p> <p>Excludes:</p> <ol style="list-style-type: none"> 1) Freight and insurance from European port 2) All installation costs. 	<p>For the supply of 4 tonne capacity BBOC - scope of supply:</p> <p>1 x complete furnace assembly 1 x complete furnace assembly (lined) 1 x burner 1 x set of hydraulic lifting equipment 1 x hydraulic lance assembly 1 x set of control equipment for oxygen/nitrogen flow measurement, burner control, furnace tilting and lance feed.</p> <p>Relative cost, 100% including licence fee.</p> <p>Excludes:</p> <ol style="list-style-type: none"> 1) All installation costs. 2) Costs of providing services 3) Freight and insurance from UK port. 	<p>For supply of one 4 tonne capacity submerged lance smelting furnace - scope of supply</p> <p>1 x complete furnace assembly (lined) 3 x submerged smelting lances. 1 x complete lance assembly</p> <p>Relative cost including licence fee was 98% of total price for supply of BBOC.</p> <p>Excludes:</p> <ol style="list-style-type: none"> 1) All installation costs 2) Cost of providing services 3) Instrumentation and process control equipment (Assumes use of existing TBRC controls). 4) Freight and insurance from from Australian port.
Cost of extra equipment (Estimates not included in relative costs)	<p>1) 1 x litharge granulator R175 000</p> <hr/> <p>TOTAL R175 000</p> <hr/>	<p>1) 1 x litharge granulator: R175 000 2) 1 x working platform R 30 000 3) 1 x spare shell R 30 000 4) 1 x essential Spares R 85 000</p> <hr/> <p>TOTAL R320 000</p> <hr/>	<p>1) 1 x Litharge granulator R175 000 2) 1 x Working platform R 30 000 3) 1 x Furnace feed system 30 000 4) 1 x lead granulator R150 000 5) 1 x spare shell R 30 000 6) 1 x essential spares R 60 000</p> <hr/> <p>TOTAL R475 000</p> <hr/>

After an exhaustive study of the three technologies the BBOC was selected on account of the following perceived advantages:

- high oxygen efficiency (almost 100%) and reduced operating costs;
- the ability to produce doré bullion (precious metal content > 98%) in one step, so eliminating the old cupel furnace;
- reduced labour complement;
- excellent fume containment even when casting;
- much improved refractory life;
- ease of operation even by operating staff with relatively low levels and skill;
- low maintenance requirements; and
- improved metallurgical accounting and security.

3 New Cupellation Plant Description

3.1 Bottom-Blown Oxygen Converter

The design parameters and dimensions etc of the new 4 ton capacity BBOC are given in Table 1. The major design and operational features are:

- fully proportionating gas fired burner;
- oxygen injection achieved using a nitrogen shrouded consumable lance, maintained in the vertical position;
- lance feed operation fully automatic and PLC controlled;
- main furnace body is water cooled;
- furnace essentially fully enclosed during all operations in order to contain all lead fume emissions;
- hydraulic system designed to provide hydraulic power to operate the tilting of the furnace body, operation of door and lid and operation of the auto lance system;
- doré bullion produced can be cast directly into anodes, eliminating holding furnaces; and
- design incorporates safety features which allow for circuits and interlocks which prevent or protect against flame failure, lance oxygen or nitrogen failure, uncontrolled hydraulic tilting.

TABLE 1	DESIGN DATA - B.B.O.C.
Rated Capacity	4.0 tons
Working volume	0.45 m ³
External diameter	1 426 mm
External length	2 488 mm
Tilt arc	125°
Maximum oxygen flow through lance	36.0 Nm ³ /h
Maximum nitrogen flow through lance	14.0 Nm ³ /h
Maximum gas flow through burner	200.0 Nm ³ /h
Thermal liberation	0.70 x 10 ⁶ Kcal/hr
Furnace cooling water	32.0 m ³ /h
Exhaust gas volume	
-hygiene door open	3000 Nm ³ /h
-hygiene door closed	7500 Nm ³ /h

The old and the new process "flow diagrams" are given in Fig. 3 and 4.

Figure 3 Flow Diagram of the old process

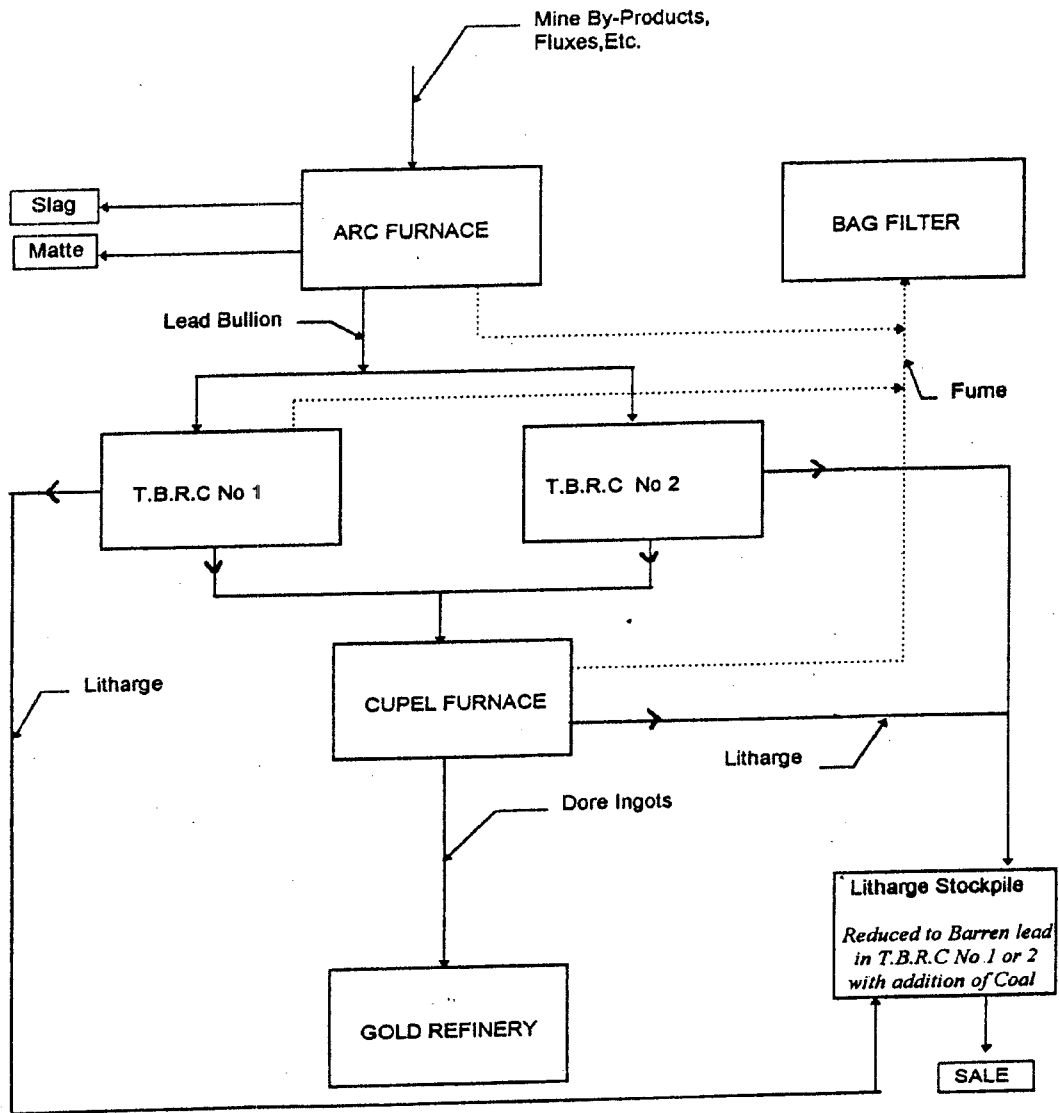
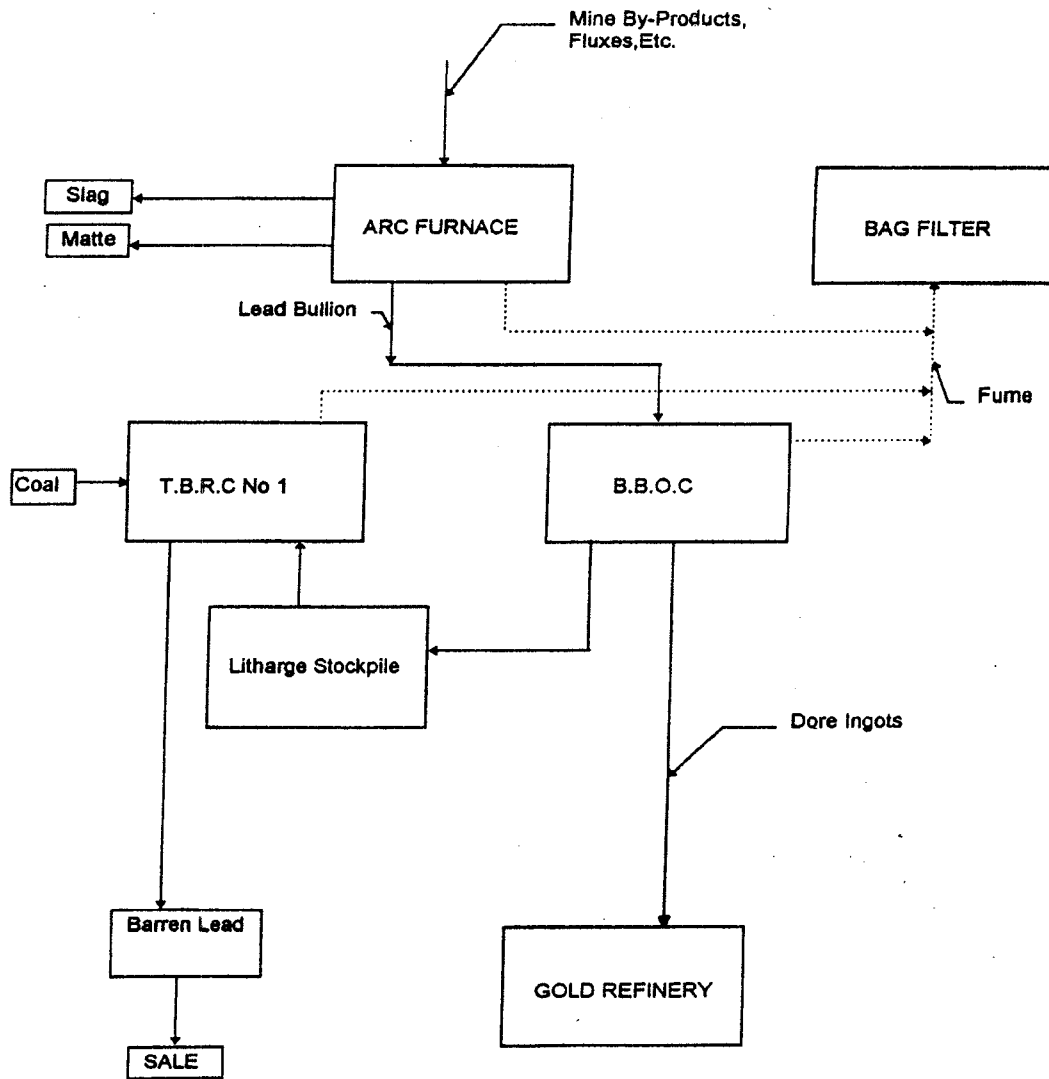


Figure 4 Flow Diagram of the new process



4 Commissioning The B.B.O.C.

The new BBOC and various ancillary equipment arrived at Rand Refinery from the United Kingdom at the beginning of August 1994. The installation of the furnace in the existing arc furnace building took six weeks to complete. The installed 4 ton BBOC, and the remaining 1.5 ton TBRC are shown in figure 5.

The BBOC was hot commissioned over a three week period during October 1994, with the assistance of two engineers from MIMTM on a 24 hours per day, 7 days per week shift basis. During this period the BBOC took over all the cupellation operations from the existing TBRC/Cupel route. The familiarisation of technical, operating and maintenance staff, with both the equipment and process was minimised because a number of smelter personnel had been sent for 10 days intensive training at MIMTM in Northfleet, during May 1994. This involved lectures and workshops relating to both operational and engineering requirements. Also included was training given on the operational BBOC at Britannia Metals Limited, which gave the operators current hands on experience.

Overall, the commissioning of the BBOC went very well with only a few minor problems. Other than getting the BBOC fully operational, this commissioning period was also used to prove that the furnace could meet specific process guarantees given to Rand Refinery by MIMTM as part of their licensing agreement.

4.1 Process Performance Guarantee

The agreed process performance guarantee is summarised as follows:

Stage 1

The concentration of up to 5 ton of arc furnace lead bullion containing a precious metal value (PMV) of $\geq 3\%$, into a concentrated lead bullion with PMV $\geq 50\%$ in a time frame for this operation of ≤ 21 hours.

Stage 2

The upgrade of up to 2 tons of concentrated lead bullion with PMV $\geq 50\%$, into doré bullion containing PMV of $\geq 98\%$ in a time for this operation of ≤ 7.75 hours.

The indicative cycle time breakdown were as follows:

	Stage (1)	Stage (2)
Charge/Melt	3.00	1.00
O ₂ blow	12.25	3.00
Pour litharge	3.25	1.25
Pour concentrated lead bullion	0.50	-
Pour dore bullion	-	1.50
Spare	<u>2.00</u>	<u>1.00</u>
	21.00 hours	7.75 hours

During both the commissioning period and the remainder of 1994, the BBOC installed at Rand Refinery Limited has generally met the process guarantee requirements (to managements satisfaction).

It must be noted that in terms of the process guarantee, the cupellation is carried out in two stages. However the furnace has subsequently been operated as a one stage process. This involves a continuous charge/smelt/slag tap cycle, until there is sufficient doré bullion contained in the furnace i.e. (± 500 kg) to tap the doré bullion out.

This provides the flexibility to operate the BBOC as either a one stage or two stage operation depending on availability of arc furnace bullion etc.

FIG 5 As installed 4 ton BBOC, and the remaining 1.5 ton TBRC.

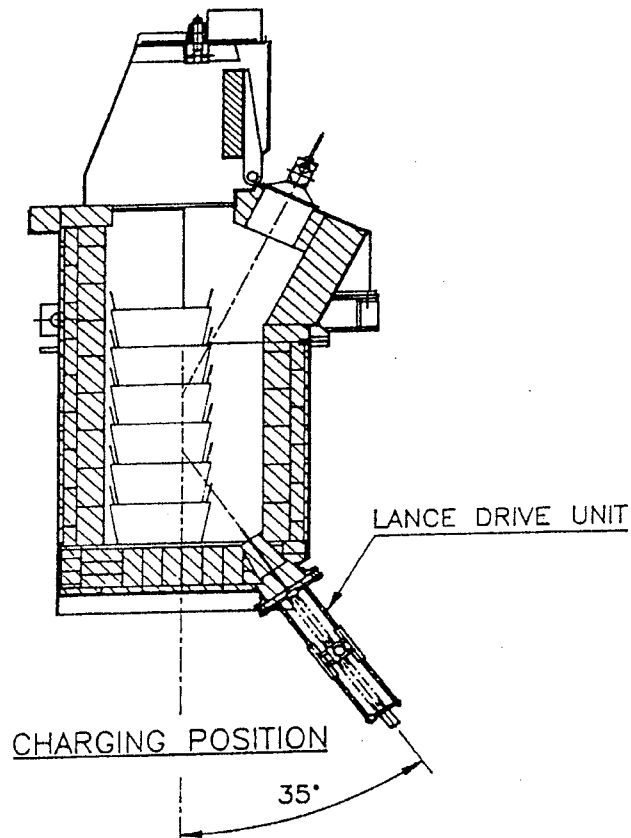


5 B.B.O.C. Operational Data

5.1 Charging

The current charging operations involve loading the converter with solid lead blocks of arc furnace lead bullion weighing ± 300 kg each, using an overhead crane. The charging position of the furnace is given in Fig. 6.

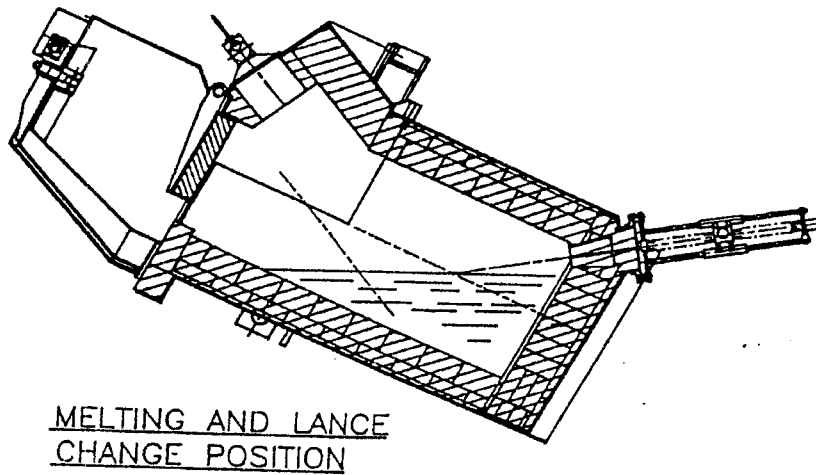
Figure 6 Charging Position



5.2 Charge Melting

The converter is tilted from the charging to the charge melting position which is given in Fig. 7. The burner is then switched on to allow melting to proceed. The charging and melting operations currently take approximately 3 hours a day.

Figure 7 Charge Melting

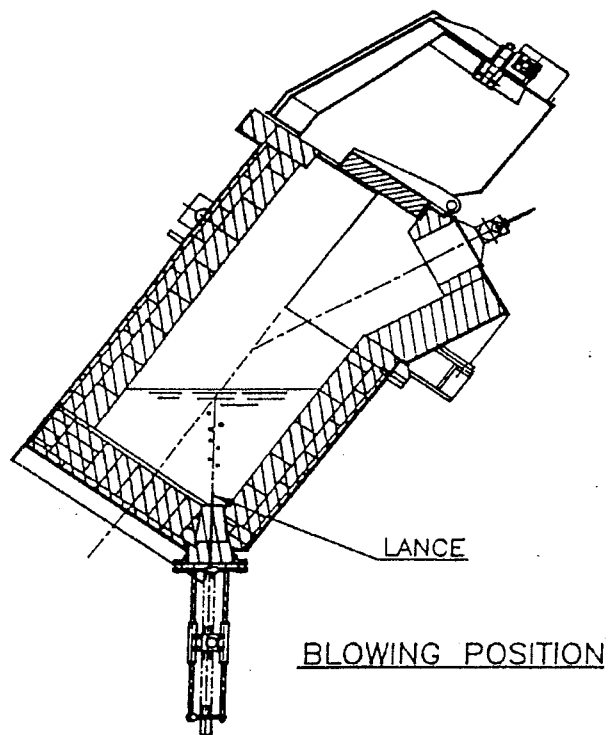


Note that the furnace must be tilted into this position to allow for the changing of the consumable lance i.e. (lance changes effected \pm every 15 hours).

5.3 Oxidation of Charge

Once melt down of the lead bullion is complete and the furnace is tilted into the blowing position, the oxygen is switched on and blowing of the charge commenced. The blowing position of the converter is shown in Fig. 8. The lead is oxidised to slag (litharge), at a rate of approximately 400 kg/hr. Approximately every three hours molten litharge is tapped from the converter. Currently the blowing operation takes 12 hours per day in total.

Figure 8 Oxidation of Charge



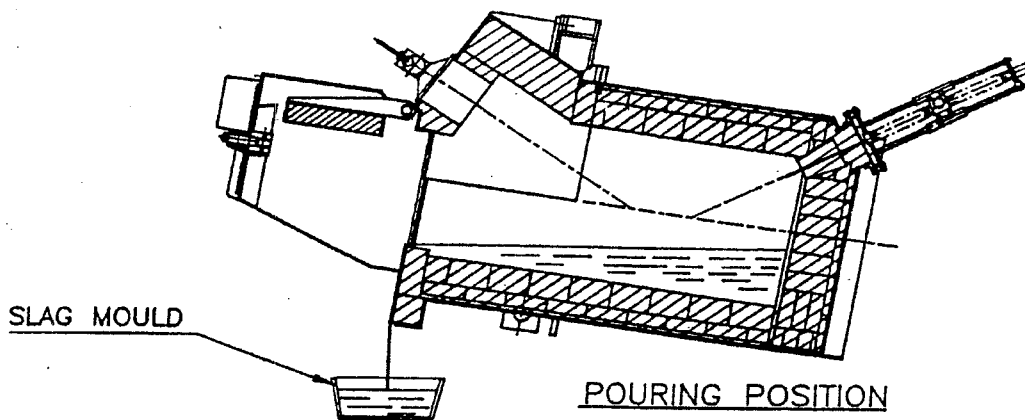
5.4 Pouring Operations

The converter is tilted into the pouring position as shown in Fig. 9. The litharge is carefully run off via a notched tapping block and is subsequently granulated into water. This operation is continued until most of the available litharge has been removed. The furnace is tilted back into either the charging position (if more solid charge is available), or the blowing position to recommence oxidation.

When pouring concentrated lead bullion from the converter, the bullion is cast into moulds which provide blocks of metal weighing ± 400 kg.

During the casting of doré bullion (which is normally carried out approximately every five days), the burner must be left on during the full casting operation to prevent freezing of the metal. The doré bullion is currently cast into mine "smelt house" moulds, which produce bars weighing approximately 20 kg.

Figure 9 Pouring Operations



6 General Comment

6.1 Initial B.B.O.C. Operating Results

It should be noted that all operating and financial results, are based only on the first three months of operation of the new BBOC at Rand Refinery i.e. October 1994 to December 1994, inclusive.

During this period, the BBOC was operational for 62 working days. For the remainder of this period, the BBOC was off line due to 14 days Christmas shutdown and to the non availability of arc furnace lead bullion. This non availability of lead bullion arose from commissioning problems encountered with the new charge and flux blending plant, which supplies feed material to the submerged arc furnace.

The BBOC was off line for maintenance and engineering problems for 5 working days, which was for minor refractory repairs to the breast and pouring block, and lance block changes.

In the 62 days the BBOC had available feedstock, it treated a total of 244.7 tons of arc furnace lead at an average of 3.95 tons per day. However the highest amount processed in 24 hours was 6.2 tons, which indicates that the 4 ton BBOC has more than sufficient capacity to process 5 tons per day of arc furnace lead bullion.

From the 244.7 tons of material processed, a total of 4980.7 kg of doré bullion was produced containing 1448.9 kg gold and 3358.8 kg silver. This gave an average PMV in the doré bullion of 96.52%, which is below the process guarantee PMV figure of $\geq 98\%$. This is attributable to problems encountered during the final oxidation process prior to the pouring of the doré bullion because the burner is barely capable of holding the temperature to around 1000 to 1020°C, which is the typical melting temperature of the doré bullion. This problem is exacerbated by the fuel Sasol gas, which has a low C.V. and gives a flame of low emissivity, especially at the altitude which Rand Refinery is located i.e. (1900 metres above sea level).

This particular difficulty should be overcome by the addition of 4% oxygen enrichment to the air/fuel burner, which will increase the flame temperature by approximately 150°C, in a modification due in February 1995.

It is worth noting that the highest doré bullion PMV result achieved during this period was 99.2%, which is higher than the process guarantee figure of $\geq 98.0\%$ PMV.

During the period under review the original chrome magnesite refractory lining of the BBOC has performed very well. Although some spalling of the bricks has been observed, wear of the bricks, especially around the normal slag/air interface area, is minimal, even after around 9 weeks operation. The breast block has been changed twice during this period, and the lance block life is typically 1½ months.

6.2 Initial B.B.O.C. Operating Costs

One of the main motivations for Rand Refinery choosing the BBOC process was that it was perceived to be a low maintenance, low cost process when compared to the TBRC's. Therefore, the relative operating cost for the periods October 1993 to December 1993 and October 1994 to December 1994 inclusive have been compared. Although it would have been preferable to use the complete 1993 - 1994 financial year as a comparison because the main smelter project commenced in January 1994, this work considerably disrupted the normal operations of the arc furnace, TBRC, cupel furnace circuit. This in turn skewed the operating costs for January 1994 to September 1994, so a cost comparison for this period would not be meaningful.

The comparative costs for the TBRC/Cupel process, and the BBOC are given in Table 2.

Table 2 Comparison of Operating Costs

	T.B.R.C./CUPEL OCT '93 to DEC '93	B.B.O.C OCT '94 to DEC '94
Refining Materials	29 208 (91)	12 890 (52)
Refractories	104 974 (326)	42 953 (176)
Sasol Gas	51 347 (160)	46 219 (189)
Bulk Oxygen	140 704 (437)	58 920 (241)
Bulk Nitrogen	- (-)	12 560 (51)
Engineering Maintenance	76 340 (237)	42 017 (172)
Employment Costs	108 000 (335)	63 000 (257)
TOTAL (S.A. RANDS)	R510 573 (1586)	R278 559 (1138)
Total Lead Processed (Tons)	321.8	244.7

Please note that the figures in brackets are individual costs in Rands per ton of lead processed. Overall, total operating costs have been reduced from R1 586 to R1 138 per ton of arc furnace lead processed to doré bullion, by the installation of the BBOC.

7 Conclusions

Based on the initial operating and financial results, the originally perceived advantages of the BBOC over the TBRC's appear to have been achieved. These are identified as follows:

- 1 High oxygen efficiencies have been achieved as indicated by a 45% reduction in bulk oxygen costs to date.
- 2 Overall operating costs have been significantly reduced from R1 586 per ton to R1 138 per ton i.e. (28.3% reduction in total costs).

- 3 The process has the ability to produce doré bullion (precious metal content $\geq 98\%$) in one step, so eliminating the need for the old cupel furnace.
- 4 The labour complement has been reduced from 3 men to 1.5 men per shift.
- 5 The fume containment during all modes of operation of the BBOC is far superior to that of both the TBRC's and the cupel furnace. This is born out by the fact that since the installation and commissioning of the BBOC, no smelter personnel have had to be removed from the smelter area with high lead in blood.
- 6 The operational refractory life of the BBOC was 13 weeks to the end of January 1995. This compares extremely favourably with an average refractory life of 2 weeks for the TBRC's.
- 7 The process has proved to be easy to operate and control. Very precise hydraulic control when tilting and lip to axis pouring characteristics ensure that all pouring operations are easy and relatively splash free. Oxygen lance operations are fully automatic and oxidation operations can be left virtually unattended.
- 8 Maintenance requirements have significantly been reduced with a costed out saving on engineering time and materials of 27.4%, when compared with the old processes.
- 9 The security integrity and metallurgical control has been radically improved by the following actions:
 - no requirement to transport concentrated bullion from TBRC process to cupel furnace process;
 - essentially a one step process i.e. (lead bullion in, doré bullion out);
 - all litharge slag is now granulated, which removes the necessity to break up solidified cobs of litharge which can contain concentrated lead and/or doré bullion;
 - all BBOC operations are monitored on CCTV and all pouring operations are recorded on time lapse video; and
 - all doré bullion pours are effected on Monday to Friday day shifts under management supervision.

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