# SINKING CONTRACTOR'S CLOSE OUT PRESENTATION ON COMPLETION OF SOUTH DEEP SHAFTS

A Douglas: Executive Director
Murray and Roberts Cementation
and
K McLeod: Media Consultant, Interactive Info

## TABLE OF CONTENTS

## 1. INTRODUCTION:

*{Figure 1}* The Placer Dome-Western Areas Joint Venture's South Deep Twin Shaft Complex, has been planned and dreamt of for nearly 20 years.

Figure 1: South Deep twin shafts

The gold reserve at the bottom of these shafts is one of the largest single intact gold deposits remaining in the world today, containing an estimated 57 million ounces. This is about the size of the fictitious reserve created by inventive prospectors for the infamous BREEX scam in Kalimantan about ten years ago and about the size of the reserve Harmony claims as its own in it's current hostile takeover bid for Gold Fields. So it is certainly of the magnitude that dreams are made of.

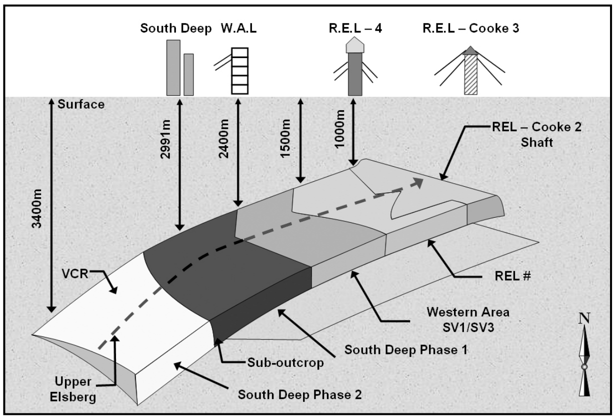



Figure 2: The orebody

*{Figure 2}* The unique orebody lies in a continuous, highly concentrated, thick deposit, an estimated twelve kilometres along dip and a two kilometre wide strike. Due to the thickness of some sections of the reef, up to 60 metres in places, bulk mining methods will be required for it's extraction.

*{Figure 3}* The twin shaft system comprises a main shaft which had an initial design depth of 2765m and a ventilation shaft of 2760m, making them the world's deepest to be sunk in a single lift. The shafts were

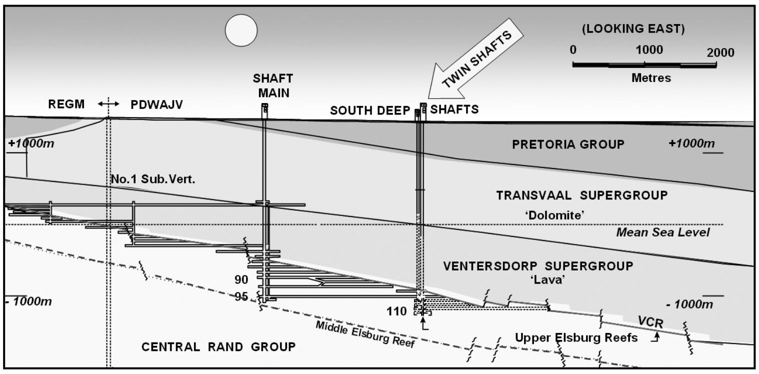



Figure 3: Twin Shaft System

eventually sunk to final depths of 2991 metres for the main shaft and 2759m for the vent shaft.

To the left of these Twins is the WAL South Section orthodox Multi Shaft complex consisting of a brattice walled Main Shaft and then secondary and tertiary sub verticals.

The shaft system is designed for efficient men and material handling, is geared for high tonnages and is unique in that it provides access to depths of nearly 3km in a single lift instead of the traditional, intricate and time

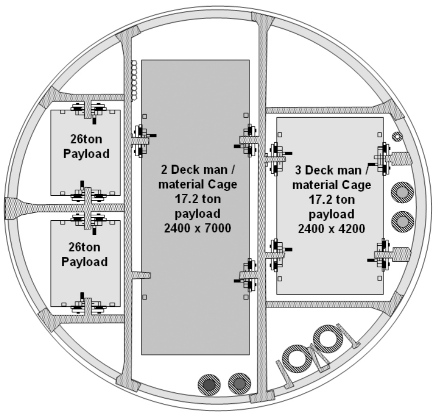



Figure 4: Main Shaft

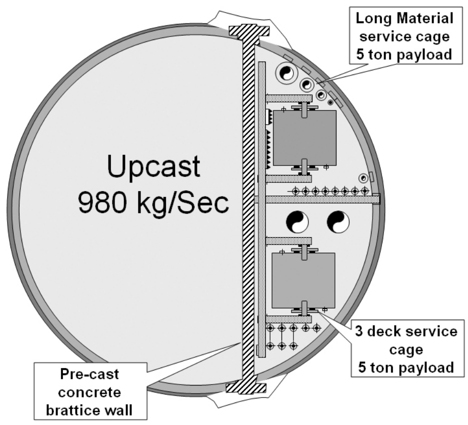



Figure 5: Ventilation Shaft

consuming, costly to install and operate, Multi-shaft systems. *{Figure 4}* The Main shaft will be used for transporting people, materials and ore. The designs were done late last century. The man/material cage description should be the more politically appropriate people or person/material cages.

*{Figure 5}* The Vent shaft will be dedicated to the upcast extraction of used air from the workings and can provide access to the workings in an emergency.

These favourable features, combined with easy access to the orebody, better working conditions promised by the improved ventilation and refrigeration systems, have the potential to facilitate and permit South Deep becoming the premier gold mine.

Figure 6: First Blast

*{Figure 6}* The project was kicked off in June of 1995 and at the time was believed to be the biggest shaft sinking contract ever awarded in South Africa at R192million. The foreground shows the successful first blast which was initiated by Tokyo Sexwale who quipped that he spent several years in Russia training as a saboteur especially for this occasion. The inset photo is of the "Letter of Intent" handover ceremony by Syd Caddy to Yours Truly, the recipient.

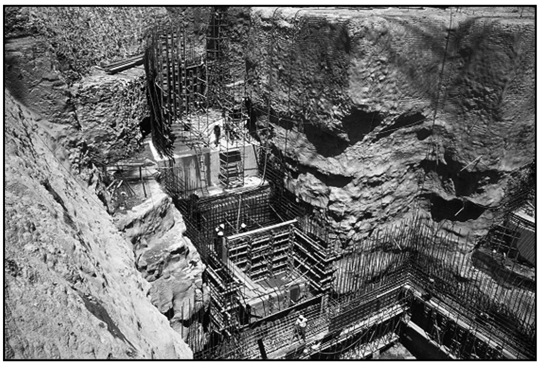


Figure 7: Main Shaft Headgear box cut

Figure 8: Main Shaft Slip Form

*{Figure 7}* Everything about the South Deep Twin shaft complex is big and size of the 22m deep box cut for the main shaft headgear was the first indicator.

Figure 9: Main Shaft Headgear

*{Figure 8}* The Main shaft headgear concrete shell took 41 days to construct and was slip-formed at a rate of 115mm per hour.

*{Figure 9}* More than 4000 tons of concrete with 480 tons of steel reinforcing was used to

erect the 93.5m high Main shaft headgear, the tallest in the world until surpassed by the Palabora Rock Shaft. An additional 700 tons of steelwork was fitted into the headgears for sinking condition.

## 2. THE CHALLENGES:

The sinking of these twin shafts presented a number of challenges to the "owner/contractor" constructors due to the extreme depths and some unexpected difficulties that were encountered. Incidentally, our response to these challenges resulted in two of our managers being awarded gold medals, one from the Association of Mine Managers for Mike Wells on the Main Shaft salvage and the other from the Association of Mine Resident Engineers for Tim Wakefield for his paper on the difficulties with the kibble ropes.

### 2.1 Taking the plunge

It was a routine Wednesday afternoon on the 1st of May 1996, the shaft bottom was at a depth of 500m below collar, when the Main Shaft Master Sinker, Martin Tribelhorn left site shortly after overseeing the last blast of the day. It was his birthday and he had just arrived at home when the call came through. "There's water", said the voice on the phone, "… and lots of it!"

So he put his boots back on and it was almost six months later, after facing down an inrush of 360,000 litres of water per hour, before the battle had been won and the shaft recovered.

Strategies and tactics, used to overcome the inundation, were the introduction of high capacity submersible pumps, the construction (in the dry) of a **1132m³** mass concrete plug and the application of a reverse flow cement grout intrusion, a technique originally developed by the **Cementation Company** for dealing with this type of emergency.

*{Figure 10}* Here we see a 16 ton kibble of water being tipped during the baling operations.

Figure 10: Baling water from the main shaft

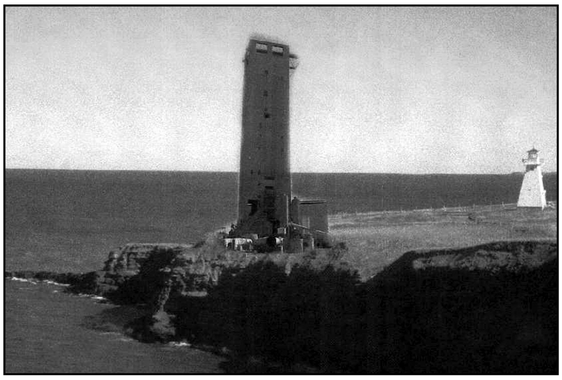


Figure 11: How miners prefer their water

*{Figure 11}* This image represents the feeling of some at the time after the shaft recovery and is indeed how we miners prefer our water, outside the shaft instead of in it.

The fissure accepted 7,5 million kilograms of cement over 40 days and nights delivered by trucks running around the clock and the dedicated efforts of the best people the client and contractor had to offer were required to recover the shaft. Sinking was recommenced after extensive probe drilling had proven the effectiveness of the seal.

## 2.2 Learning the Ropes: The Kibble Ropes

Another interesting and unexpected challenge came from the steel wire ropes used for kibble hoisting, which had a tendency to deform due to the high stresses induced by great depths and heavy loads.

The kibble ropes carried a 16 ton payload of rock on the 3km trip from shaft bottom to the tip at an average speed of 15m per

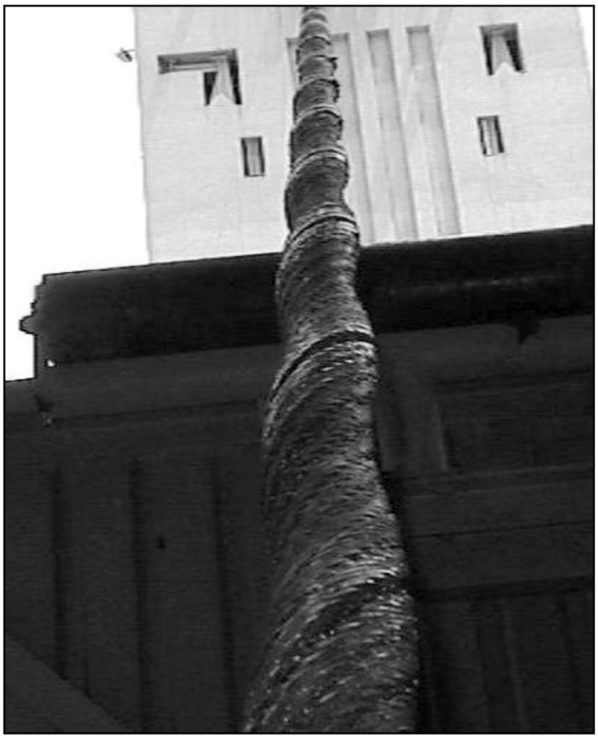


Figure 12: Deformation of the kibble ropes

second or 54km/hour. The first indication that something was amiss was this "waviness" that developed on the underlay rope front end.

*{Figure 12}* The deformation was visually spectacular, however, the ropes were actually well within their safe working limits and at no time did we compromise safety. Constant consultation between ourselves, the client, the rope manufacturer and the inspectorate enabled us to weather these difficulties.

*{Figure 13}* This special device was employed to run up and down the ropes and iron out kinks, an elementary, but effective remedy. The ropes were eventually replaced. Investigations carried out to determine the cause of the problem were inconclusive.

Figure 13: Device to iron out kinks in the rope

The main contributing cause of the deformation is thought to be excessive tread pressure, both at the sheave and winder drum. These conditions are exacerbated/alleviated by a series of secondary factors, such as friction, wire and strand configuration, etc. rope construction and laying up.

The shaft has been working in permanent condition mode since November 2004 and the problem appears to be resolved. Parameters that have altered since then are:

1.) Tread pressure and internal friction has been reduced by using two Lang's Lay ropes as designed for the multi rope Blair Winder, instead of the sinking condition, single rope per conveyance configuration

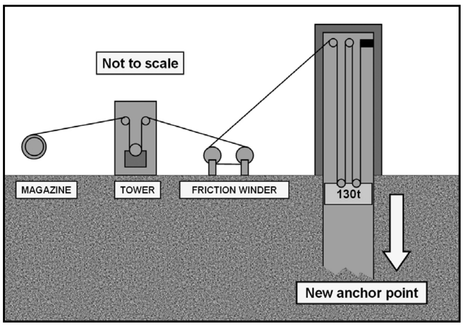
2.) The rope ends are now fixed to the conveyance, whereas in sinking conditions, they are free to rotate in the crosshead.

## 2.3 Going the extra Mile: Rope Anchor on 84 Level

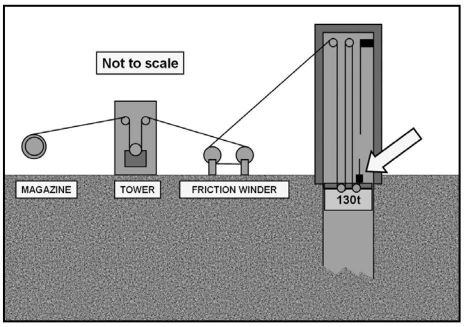
The Main shaft was initially designed to go down to 2765m, this required 4 falls per rope to suspend the sinking stage.

*{Figure 14}* The total length of each rope was 11.5 kilometres. The ropes were delivered to site on these two bobbins. When the design depth was later increased to 2995m, the extra rope length required worked out to an additional 980m or 1km.

Figure 14: Kibble rope bobbins




*{Figure 15}* This challenge was overcome by the elegant expedient of moving the anchor point 1km below collar, so reducing the rope length requirement. To achieve this, the stage was secured just below bank and the headgear anchored rope end transferred to the stage. The stage was then lowered down to 84 level and once again secured.



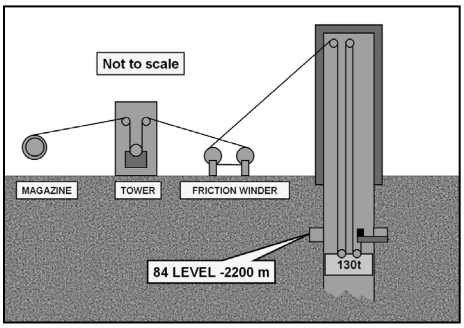




Figure 15: Compensating for the additional 980m of rope required

The dead end was then transferred to a specially designed anchor point in the shaft sidewall. Sinking could then continue to 2995m.

*{Figure 16}* This is the Rope Reliance clamp on the anchor point from which the stage rope was suspended.

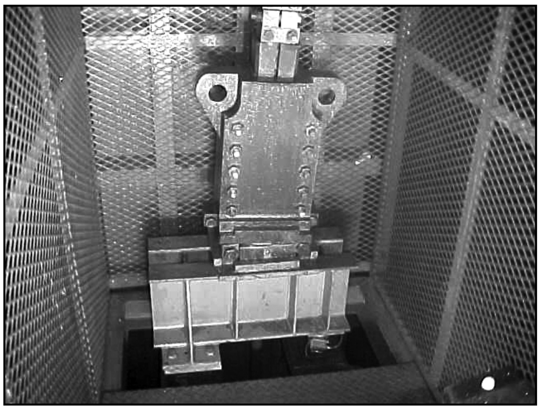


Figure 16: Rope reliance clamp

## 2.4 Holing into the backfilled stope

In a calculated move to destress the thick Elsburg orebody at the shaft pillar position, the overlying Ventersdorp contact Reef shaft pillar, 2335m below surface, was removed before he shafts were sunk.

*{Figure 17}* This was removed through the workings of the existing, adjacent South Mine and was completed 13 months before the planned holing.

The excavation was backfilled with a stiff cementitious paste. This fill was then moiled out to 1m around the shaft perimeter and supported before sinking continued.

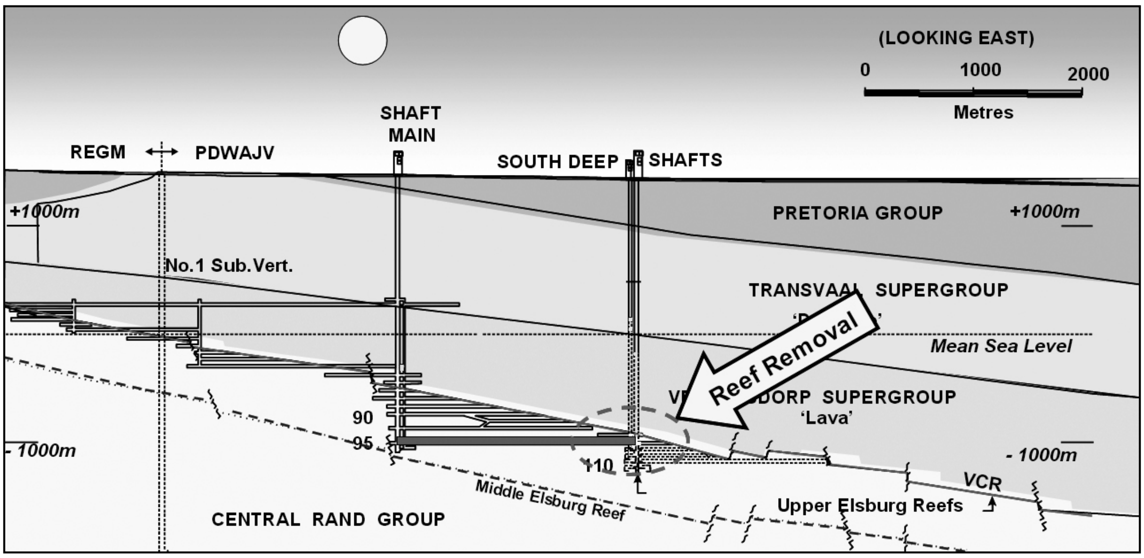



Figure 17: Holing into the backfilled stope

## 2.5 Sinking through the Destress Zone

Rock mechanic computer simulation showed that the shaft barrels would be destressed for 385m above the extracted pillar.

*{Figure 18}* This destressed zone required special support in the form of a customised mix of Belgian designed stainless steel fibre reinforced wetcrete, combined with 6m long rope anchors.

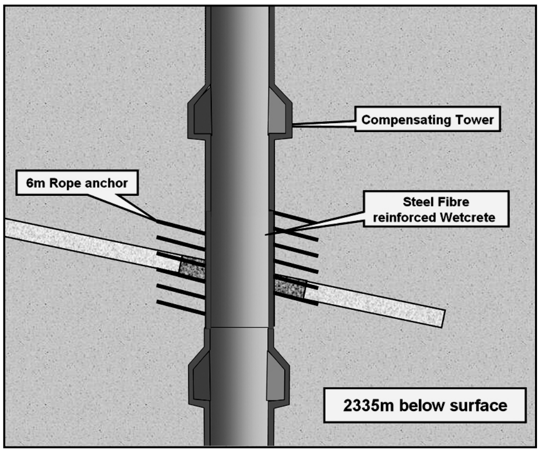



Figure 18: Schematic of secondary support used

It was expected that the shaft would compress enough over time to disturb the accurate alignment of the guides which could in turn disrupt travel in the shaft. To overcome this anticipated deviation from true, a flexible, compressible, hanging, compensating tower was designed to absorb this shaft depth shrinkage and guide the conveyances through the destress zone.

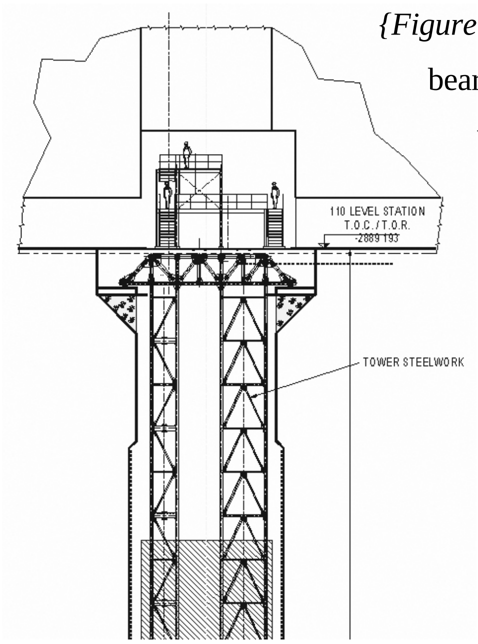



Figure 19: Side view of the Steel Tower

*{Figure 19}* This steel tower hangs from three different bearing bridges, forming an interlocking cage through which the conveyances can travel. The entire structure can be manoeuvred and realigned if major movement is detected by the 7 sensor rings that have been attached to monitor the movements of the destressed zone.

The Tower is situated between 2300 and 2700 metres below collar and is the largest such structure ever installed.

*{Figure 20}* The compensating tower spans 84 to 100 Level and if fully erected on surface to it's 385m height, would tower above the Carlton

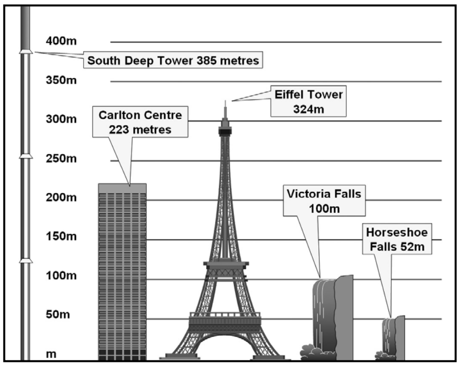



Figure 20: Compensating Tower height comparison

Centre's 223m. It comprises 3 main sections and was pre-jigged on surface, marked and numbered. The entire structure was then taken apart and the numbered pieces sent to down for re-assembly in the shaft.

One set took 72 hours to install. We can normally install 9 sets per day in fixed buntons. A second tower was installed from 110 Level for 18metres to transit the K8 shale intersection.

## 2.6 Stations

*{Figure 21}* A similar routine was followed with the station steelwork also being pre-assembled on surface and thereafter disassembled for transport down the shaft in sections for final erection.

Figure 21: Station pre-assembled on surface

## 2.7 Final Main Shaft Equipping

*{Figure 22}* Equipping was done from the top down. The equipping of the Main shaft with steelwork, started on 27 February 2003 and continued 24 hours/day for 21 months, until finally on 17 November 2004, the task was complete and 3,600 tons of equipping steel had been installed, comprising 2500 tons of guides and 1100 tons of buntons.

Figure 22: Main Shaft equipping

Every piece of equipping steel installed was galvanised, pre-jigged and installed under the full-time supervision of quality assurance inspectors. The Main shaft also absorbed 1000 tons of steel for the headgear structure, 520 tons for stations, 750 tons for the suspended tower, 1400 tons for services piping and an impressive 430 tons of fasteners.

The total shaft steelwork used for the Main Shaft amounts to some 7700t, which is more than was used to build the Eiffel Tower.

## 3. INNOVATIONS:

New technologies constantly emerge. The prevailing climate on this job was of innovation, which led to a number of new tricks being tried. These included:-

### 3.1 The use of pumpable explosives

Figure 23: Pumpable explosives

*{Figure 23}* Unfortunately this trial was terminated because of excessive water in the shaft bottom. The kibble ropes were required to sling the explosives container, meaning that bailing was interrupted while the explosives container was slung. The water make into and below the shaft bottom was of sufficient quantity to disturb the pumping of explosives into the shot holes.

### 3.2 Long Rounds

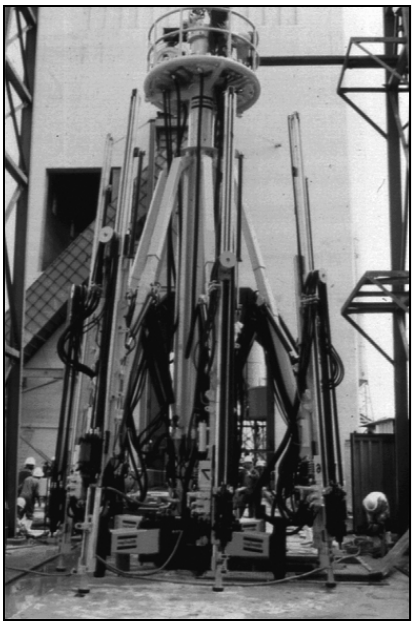


Figure 24: Atlas Copco Jumbo drill rig

*{Figure 24}* Due to the large diameter and depth of the main shaft it was decided to modify the standard Atlas Copco drill rig and to use the opportunity to achieve 6m long rounds. The Jumbo sized rig weighed in at 22tons and included a down the hole hammer, capable of drilling a 7m by 200mm diameter stab hole. The drill was designed to drill 6m blast holes in a single pass.

Although the long rounds never really achieved the breakthrough productivity improvements hoped for, it was proven that 6m rounds can be broken in all rock types within and overlying our Witwatersrand system. The number of long rounds eventually pulled constituted too small a sample to derive any statistically based conclusions. We attained, but did not beat our call by a significant margin, whatever round length was used.

## 4. SAFETY:

The Twin shafts achieved superb safety records and a total of 917,698 Fatality Free Shifts were recorded at the end of 2004, with a 12 month rolling average Lost Time Injury Frequency Rate of 0.00 at Main Shaft.

The Vent shaft remains the world's deepest ever constructed without a fatality, not only a signal achievement, but also a miracle and a record likely to last a long time.

## 5. THE PEOPLE:

This massive project would not have been possible without the contributions of hundreds of people involved in planning, developing, construction and engineering who have contributed their skills, labour and stress filled years of their lives to this project.

## 6. WISH FOR THE FUTURE:

*{Figure 25}* The commissioning of the South Deep Shaft complex gives South Africa access to one of the largest known gold ore bodies in the world with an estimated 70 year life of mine. Murray and Roberts Cementation is proud to have been a pioneering partner in establishing this access to our nation's future prosperity, so continuing our century old tradition of contributing to the development of this national industry and the economy.

Viva South Deep, Viva Gold!

Figure 25: "Beyond 2000" - a South Deep milestone, sinking through 2000m during the year 2000

## 7. ACKNOWLEDGEMENTS:

The authors wish to thank the Main Shaft Master Sinker Martin Tribelhorn for his assistance in preparing this presentation.

## 8. REFERENCES:

1. Wakefield T., Wallace I. and Davidtsz P.
   *Rope Experience gained from sinking the South Deep Main and Ventilation Shafts*
   Mine Hoisting 2000, 5th International Conference, September 2000

2. Wells M.F.
   *Construction of a Concrete Plug in the South Deep's Main Shaft to seal off a major water intersection*
   Journal of the South African Institute of Mining and Metallurgy 1999