State-of-art shaft system as applied to Palabora underground mining project

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Synopsis

As the world continues to face the turmoil of the economic environment, legislative prerequisites and physical conditions the intervention of technological development is vital for the continuation of the ancient source of revenue: mining.

The Palabora underground mining project is a state-of-the-art shaft mining system that will prove to be a benchmark in its field for years to come. An integration of modern technology—both in application and development—has resulted in a shaft system that is intrinsically holistic. Every aspect of the mining and production process has undergone thorough investigation, simulation and innovation to ensure that every component is selected by design and not simply conforming to past practice or trends. The process philosophy includes proven technology such as to promote the lowest operating cost and process time with the highest yield. The underground mining system is in the final stages of commissioning and will shortly be producing a nominal 30 000 tons per day with a predominantly automated system.

This paper discusses the complete state-of-art shaft system developed for the Palabora underground mine, and refers particularly to the headgear, the winders, the conveyances and the shaft guide system, as well as the loading system developed specifically for the high performance requirements of the mine.

Overview

The existing Palabora Mine, situated at the town Phalaborwa in the Northern Province of South Africa, is an open pit operation producing mainly copper. The open pit is approaching the end of its life and hence an underground mine has been planned so that the orebody can be exploited for a further twenty years.

A nominal production rate of 30 000 tons/day from a 500 m vertical block caving operation has been planned. The caved ore is drawn through 172 drawbells, loaded by load-haul-dump units (LHDs) and hauled to four jaw crushers situated on the northern side of the foot print. The -200 mm crushed ore from the silos underneath the crushers is conveyed by a 1325 m long inclined belt conveyor to two storage silos situated at the production shaft on the eastern side of the mine. From the two storage silos at the production shaft, the ore is loaded into 30-ton skips and hoisted to surface. On the surface, the ore is delivered to existing stockpiles, feeding the processing plant, by an overhead belt conveyor system.

The total project budget is in the region of R2.3 billion. The project began in March 1996 and is expected to continue until November 2003. The sinking and equipping of the service shaft was completed in June 1999 and the roping up and commissioning was done in November the same year. The sinking of the production shaft was completed in August 1999. The two winders were installed by December 1999 and the final headgear construction for the permanent configuration commenced at the beginning of the year 2000. The service shaft is currently in operation and the commissioning of the production shaft will be completed by the end of November 2000.

Holistic system

The design of the shaft system was undertaken considering the entire mine as an interdependent system and not merely a series of processes and operations that ultimately fulfil the task of extracting the desired product. This enabled every component to be selected such that it best facilitates the operation of those processes with which it interacts.

The feasibility study was executed between July and December of 1995 and provided a complete conceptual design for the Palabora underground mine. It was necessary to establish the basic structure and philosophy of the entire shaft system and mining process. This was achieved by utilizing the integrated experience, expertise and knowledge of the owner, the Palabora Mining Company, AATS as the engineering consultant and various equipment suppliers. Sinking contractors, Shaft Sinkers, early involvement was deemed necessary to provide design input from a

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Figure 1—Aerial view of the headgears next to the pit

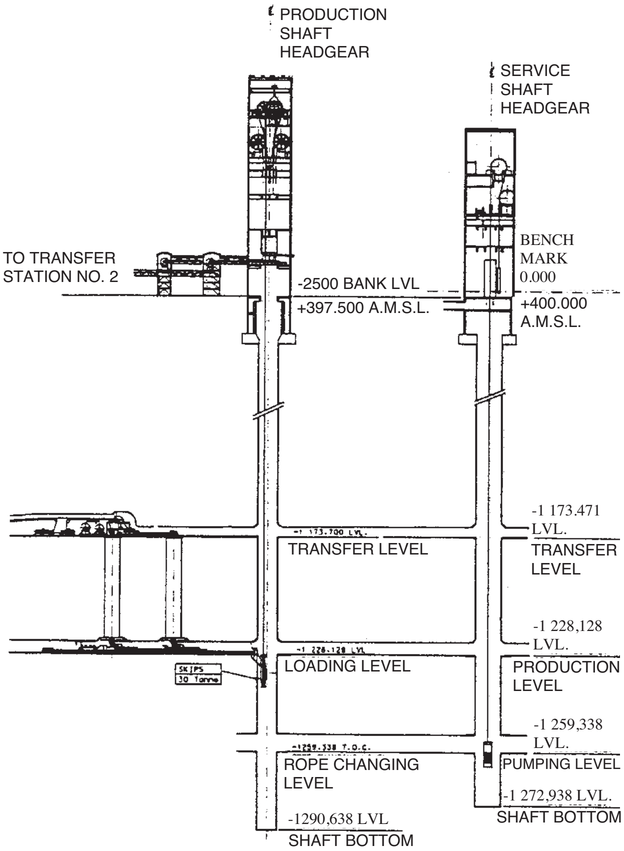

Figure 2—Shaft system cross-section

sinking consideration. Once the concepts were defined the entire system from block cave mining through to the process plant was simulated on computer using the SIMAN simulation language. The outputs were used to balance and ensure the optimum size and number of individual components to produce 30,000 tons per day: the LHDs, the tip-crusher-sacrificial conveyor units, the conveyors, the silos, the skips and winders as well as the surface storage bins and conveyors.

Configuration

Four shafts service the underground mine: a service shaft, a production shaft, a ventilation shaft and an existing (deepened) exploration shaft.

Production shaft

The production shaft is 1 290 m deep, 7.4 m in internal diameter and lined with 300 mm thick concrete. The shaft is equipped with four skips operated in pairs by two 6.2 m diameter tower mounted Koepe winders, with integrated motors. Each skip is guided in the shaft on four guide ropes and four tail ropes balancing the system. A single loading station is located at the bottom of the shaft.

The production shaft has a concrete headgear, which accommodates the two Koepe winders and each winder drum carries four head ropes. Deflection sheaves of 6.2 m diameter are used to deflect the head ropes to the skip compartment centres.

Service shaft

The service shaft is 1 272 m deep, 9.9 m in internal diameter and lined with 300 mm thick concrete. The service shaft accommodates one large single deck man and material cage and a single deck Mary Anne cage each hoisted in conjunction with a counterweight.

A purpose-designed skeleton can replace the man-material cage for abnormal loads to be hoisted in the shaft.

The Mary Anne cage and counterweight and the man-material cage counterweight all operate within rope guides.

The service shaft has a concrete headgear that accommodates the 6.2 m diameter man-material winder and the Mary Anne winder.

The tower mounted man-material Koepe winder is equipped with six head and tail ropes of the same size and construction as the production winders as detailed in the section on rope specification. The Mary Anne winder is equipped with two head ropes and a single tail rope.

Winders

Tower mounted Koepe winders

State-of-the-art 6.2 m diameter tower mounted Koepe winders with integrated synchronous motors, supplied by Siemag of Germany (previously GHH), and Siemens are utilized for the production shaft and for the man-material winder. Similar winders have been in operation in Germany at the Bergbau AG Westfalen Haus Aden Colliery since 1987. However, those used at Palabora (shown in Figure 5) will be the first in Africa.

The Mary Anne winder is a 3.35 m diameter conventional 2 rope Koepe winder driven by a motor and gearbox train.

The winder drums were sized for a maximum tread pressure of 1.72MPa.

The primary reasons for utilizing these winder drives were as follows.

Firstly the shafts and headgear are being constructed in an existing mining and production area. The space available around the headgear is restricted by the close proximity of the opencast pit on the one side and buildings, such as workshops, stores and offices, on the other.

It was necessary to erect sinking winders and with the confined space available around the headgear, this did not facilitate the concurrent installation of ground mounted

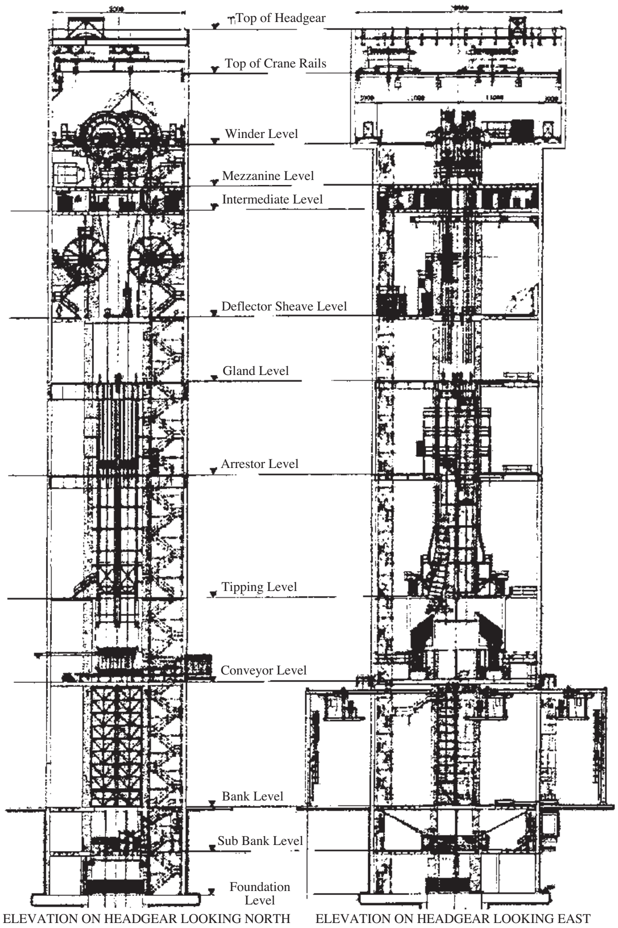

Figure 3—Production shaft headgear

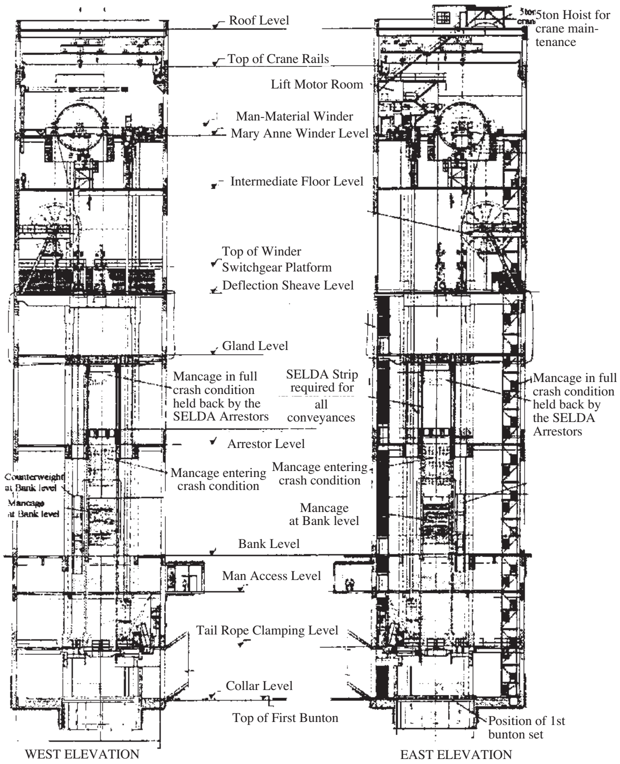

Figure 4— Service shaft headgear

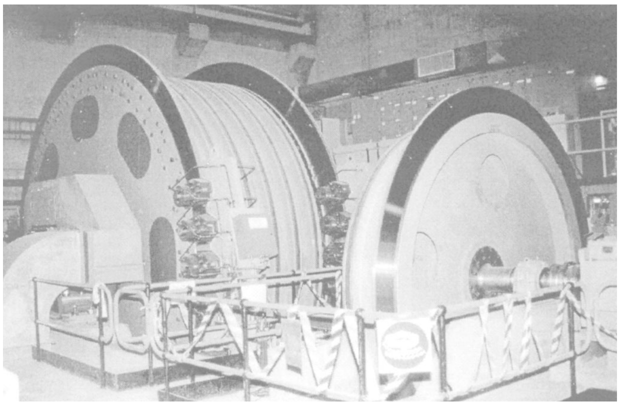

Figure 5—The tower mounted Koepe winders

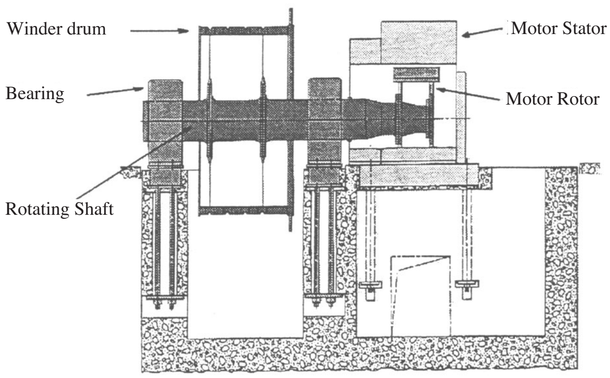

Figure 6—Conventional motor

Koepe winders. The only location for the permanent winders was at the top of the headgear.

Secondly, conventional Koepe winders, with external motors require more floor space and the two winders would have to be mounted on separate levels so that the drums would align with the current shaft compartment centres. This configuration would result in a higher headgear being required, and added cost.

The introduction of integrated motors in the winders made it possible to mount both winders side by side on the same level. The compact design and absence of gearboxes ensure a simple and proven winder drive. Mechanically: less maintenance is required and increased reliability is assured.

Integrated motors

For a comparison of conventional and integrated motors see Figure 6 and Figure 7.

Conventional winders incorporate motors and drums installed separately. They may also include a gear configuration to reduce the motor speed and increase the torque applied to the winder.

Integrated motors are effectively wound into the drum and hence with fewer components are far more robust and reliable. The large diameter of the stator/rotor results in a high torque being applied by the motor to the drum. As it is essentially a directly coupled drive the losses are minimized.

The construction of such integrated motors is an art form

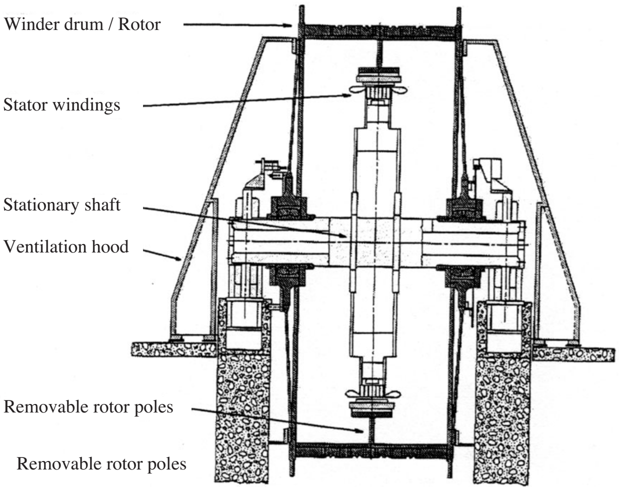

Figure 7—Integrated motor

in itself as can be seen in Figure 8 below.

Power supply

The 6.4MW production winders power supplies is brought from the 11kV bank substation, forming a cable ring feed to both production winders. Each leg capable of supplying power to both winders. An 11kV circuit breaker feeds three dry-type transformers. Each of the secondary transformers feed the two 6 pulse cyclo-converters, providing 12-pulse drive for the synchronous winder motor. A separate feeder is connected to the dry type excitation transformer. The secondary voltage from this transformer is controlled by the PLC via the corresponding converter. As shown in Figure 9.

The 3.2MW man-material winder is powered identically as mentioned above. The 100kW Mary Anne winder has an 11kV feeder connected to a dry type transformer (11kV to 550V). The secondary 550V is fed directly to a six-pulse converter coupled to the DC winder motor. A thyristor panel includes the excitation equipment.

Braking system

Both the production shaft winders and the man-material cage winders use disc brakes for improved braking capabilities and less complex configuration than calliper brakes. The main reason for using them is a less complex load path and therefore reduced number of components.

Control

Both the production shaft winders and the service shaft man-material winders use AC control, whereas the Mary Anne winder is DC controlled.

Automatic rock winding

The winders are controlled by digital Closed Loop Control (CLC) incorporating a supervision overview system via a PLC. The control system will operate via a 24V battery buffered power supply to orderly shut down in the event of a power failure.

The CLC system—Simadyn D—provides position dependent speed control at the ends of the shaft and for exact positioning of the conveyance during automatic operation, and for the speed and torque control of the drive. It has an active 'jerk' limitation to reduce dynamic rope loads and hence promotes longer rope life and increases safety.

This supervision overview system provides efficient speed control by providing a speed-shaft envelope, speed referencing and active control. The shaft counter supervision and synchronization is also driven by this system. Other control and supervision aspects incorporated into the overview system are over-winds, tension of the head and guide ropes, rope slip and motor protection (I^2t and E-fault).

The position sensing is achieved by pulse generators driven from each drum, which give a resolution of approxi-

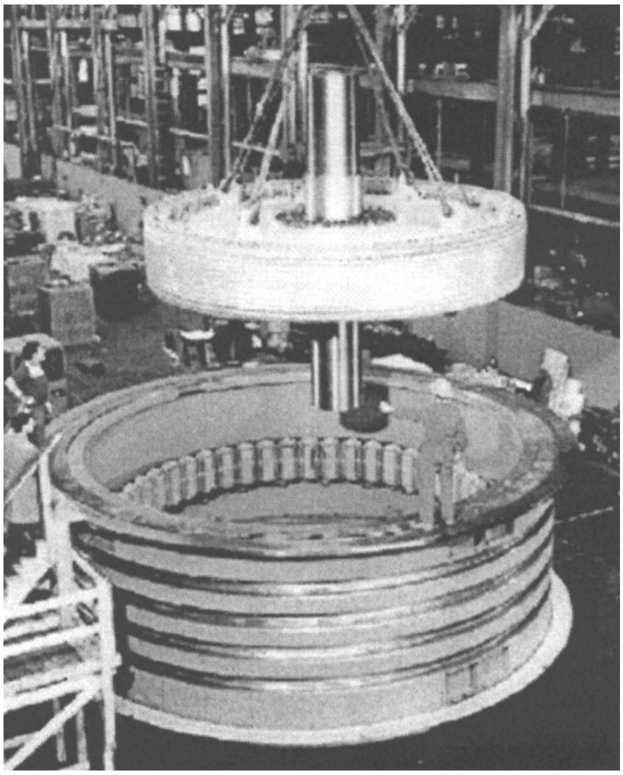

Figure 8— Assembly of Koepe winder with integrated motor

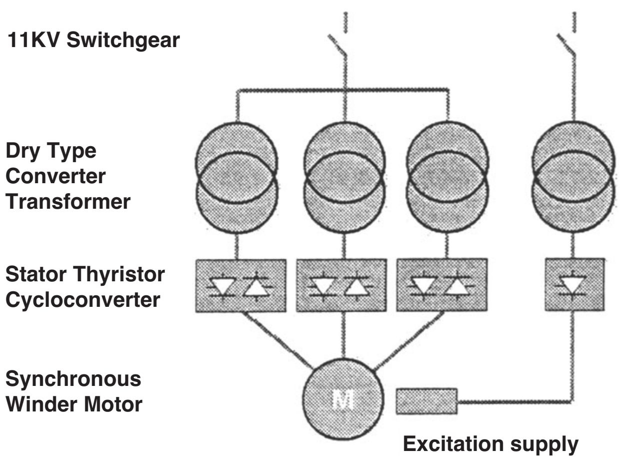

Figure 9—AC Winder power configuration

mately 1 pulse per cm. The actual position is set by means of magnetic synchronizing switches (near the top and the bottom of the shaft for each conveyance), and at the same time compensation is achieved for rope stretch or creep. At mid-shaft ultrasonic devices and lasers may be used for position monitoring of the conveyances as they travel through the shaft. As rope guides are used, a greater amount of lateral movement of the conveyance, compared to conveyances in conventional steel guides, is expected and unforeseen or hazardous conditions must be identified immediately.

A winder driver's control desk has been developed for use at Palabora. The design parameters for the desk is that it should be ergonomically styled and compact without compromising the functions of a conventional winder control desk. Hence, it has full functions with brake and speed control levers. Indicators for brake pressure, speed, torque and excitation current and shaft position, as well as standard lock bells and an intercom system are also incorporated. A multifunction LCD display provides diagnostic and status details.

The rock winding control is fully automated and is monitored from within the centralized control room. Manual operation is also available when commissioning, shaft inspection or maintenance is performed.

The man-material winder

The man-material winder is essentially controlled in the same way to that of the rock winder, with the same control instrumentation and equipment.

However, the man-material winder has three modes of operation: auto operation (like an elevator), simplex and duplex operation.

- *Auto operation*—cage control: The attendant travels with the cage. The in-cage control is activated by means of a key. All signals are sent from within the cage and no banksman or winder driver is required.
- *Simplex operation*—men winding: No winder driver or banksman is required to be present. The attendant travels with the cage. The cage is only controlled from the shaft side boxes, located on the stations, and must be activated by a key. No shaft bells are used.
- *Duplex operation*—man-material winding: Either; A banksman receives and dispatches the cage from the bank. Dispatch only takes place between the bank and the onsetter. No shaft bells are used and no winder driver is required to be present.
  Alternatively; A winder driver is present for manual winding operation of men and/or material. Communication is via a lockbell system between the driver and the onsetter or banksman. No control is possible from within the cage.
- *Shaft inspection*: Control is via an inspection pendant used by the operators from the top of the counterweight or conveyance. Voice communication is directly to the central control room.

Communication

For the man-material cage and the Mary Anne cage all data is transmitted via microwave radio link (Ecam). The skips and the counterweights utilize transducers connected to the conveyance and the headgear. The transducers use the rope as the communication medium. All signals are transmitted from the headgear via an Ethernet fibre optic link to the central control room.

Conveyances

The conveyances underwent an extensive design process that involved simulation for optimization of size and capacity.

Skips

The skips used in the production shaft have a design capacity of 32 ton, but will initially operate at 30 ton. They utilize the latest skip design philosophy which incorporates both aluminium and steel for an optimum strength-to-weight ratio and results in a tare mass of 22 400 kg per skip.

Man-material cage

The cage was designed with a life of 20 years having a corresponding 1,400,000 winding cycles.

The man-material cage can carry 225 persons and has a maximum payload of 35 ton. The construction consists of a steel frame for strength and aluminium panels and sections to minimize the mass and results in a self-weight of approximately 42 ton. The cage is 3.4 m (wide) x 9.1 m (long) x 7.9 m (high) and was designed such that all the underground machinery that will be serviced in the surface workshops can be hoisted in the shaft without dismantling. The largest item to be transported in the cage is expected to be the Toro 501 LHD and this determined the payload of 35 ton and the dimensions of the cage. The LHD bucket is detached during hoisting.

The man-material cage operates with a 59 ton counterweight.

Abnormal-load skeleton

When abnormal loads, such as crusher components, need to be hoisted in the service shaft, the man-material cage is removed and a purpose designed skeleton with a payload capacity of 48 tons is installed.

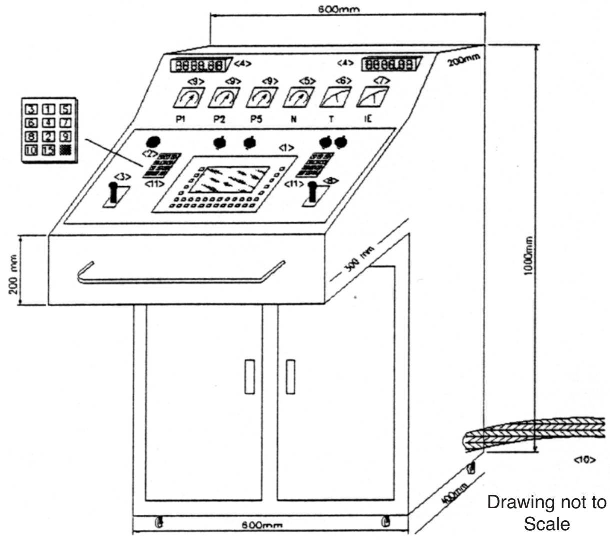

Figure 10—Winder driver's control desk

Mary Anne

The single deck Mary Anne cage has a capacity of 1.4 ton and can carry 20 men. It has a self-weight of 2 ton and is 1.625 m (wide) x 1.6 m (long) x 2.5 m (high)

The counterweight used in conjunction with the Mary Anne weighs 2.7 ton.

Ropes

Rope specification

The ropes were selected after studies conducted by the project team with assistance from various rope manufacturers indicated that, under the operating conditions, the best rope life could be expected from this specific selection of ropes.

The nominal rope specification can be seen in Table I with Figure 11 showing the construction of each rope.

Rope installation

A mechanized rope installation system is incorporated in the shaft arrangement. This promotes minimum downtime, reduced labour requirement and less risk of rope damage during maintenance and rope changing or installation procedures of the head and tail ropes.

Rope lifting device

A hydraulic rope-lifting device is installed to facilitate rope and attachment maintenance by creating slack rope.

As indicated in Figure 12 it can be installed or positioned for application in either conveyance A or B when used in the production shaft.

Head rope installation winch

The winch enables all the head-ropes of one pair of

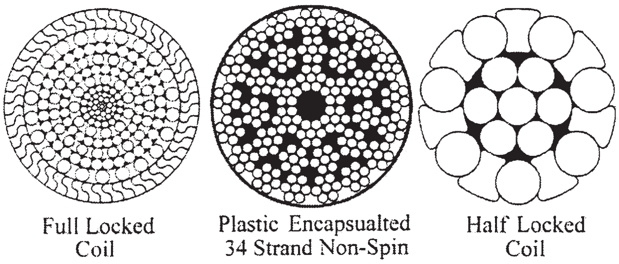

Figure 11—Types of ropes in use

Table I

Rope specifications for rock winders and man-material winder

	Head ropes	Tail ropes	Guide ropes
Type	Full locked coil	Plastic encapsulated 34 strand non-spin	Half locked coil
Breaking strength Mass/Metre Diameter (including sheath)	1 965 kN 13,00 kg/m 48 mm	1 729 kN 13,23 kg/m 54 mm (58 mm)	1511 kN 10,92 kg/m 45 mm

Table II

Rope specifications for Mary Anne winder

	Head ropes	Tail ropes	Guide ropes
Type	Full locked coil	Plastic encapsulated 34 strand non-spin	Half locked coil
Breaking Strength Mass/Metre Diameter (including sheath)	309 kN 1,95 kg/m 19 mm	400 kN 4.00 kg/m 30 mm (34 mm)	1511 kN 10,92 kg/m 45 mm

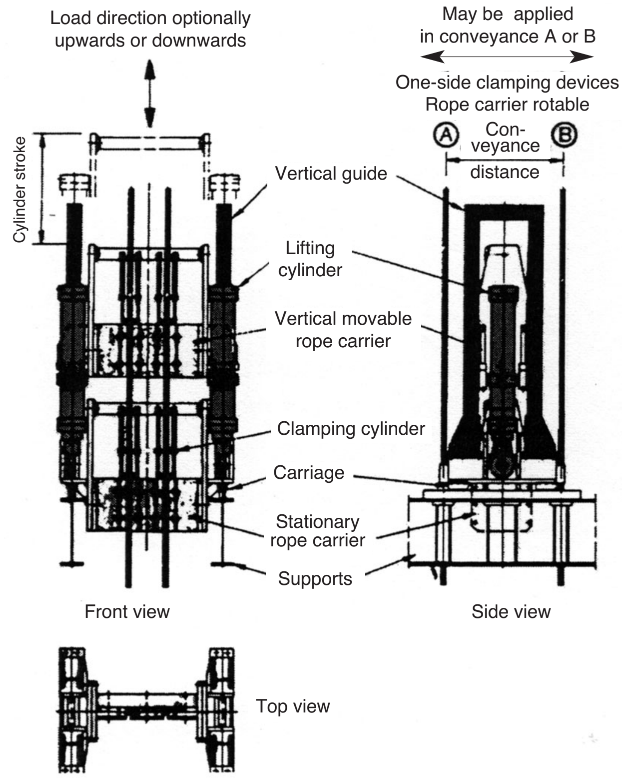

Figure 12—Rope lifting device

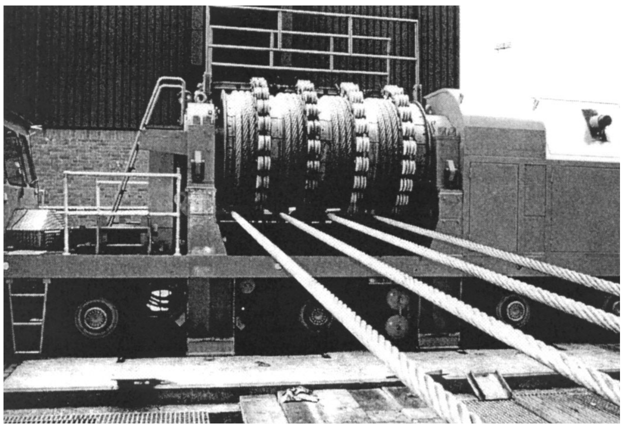

Figure 13—Mobile rope changing winch

conveyances to be installed or changed simultaneously—six head ropes for the service shaft and four for the production shaft. It removes the old head ropes and installs new ropes on the same winch. The winch was designed as a mobile trailer-mounted unit, facilitating rope changing or installation in either of the shafts using the same system. The winch can provide 1 500kN of rope pull.

The method of rope installation or changing involves securing the winch to prepared foundation bolts. Skid-mounted rope reelers are positioned behind the rope changing winch to supply and store new and old ropes respectively.

Guides

Initially the skips in the production shaft were to be guided by means of rope guides and the service shaft was to be equipped with conventional steelwork. However, after further consideration and simulation it was decided to utilize rope guides in the service shaft, in the operation of the Mary Anne and its counterweight and for the counterweight of the man-material cage.

Rope guides

The skips, Mary-Anne cage and both counterweights operate on rope guides. All these conveyances are guided in the shaft on four 45 mm diameter half-locked coil guide ropes, except for the Mary Anne counterweight requiring only two guide ropes.

The lateral stiffness is provided by the rope tension and thus there is no steelwork required between stations.

The main reasons for considering rope guides were as follows:

- ➤ Reduced cost (this is subject to various conditions, especially life of the mine as replacement of ropes or shaft steelwork add significant operational costs)
- ➤ Installation time is reduced once the headgear and shaft bottom construction is complete. Typically two weeks compared with three months as experienced with the service shaft.

Careful planning is vital to the safe operation of installing guide ropes. Palabora Mine made use of the services of experienced personnel from Canadian operations, the rope supplier Haggie Steel Ropes and the winder supplier Siemag of Germany.

South Africa currently has no clearance regulations for rope guides. Table III lists a number of foreign regulations for rope guides. These regulations assume a shaft depth greater than 500 m, no rubbing ropes and smooth sidewalls.

Palabora Mine received exemption from the above South African regulation and will operate with a Rope Guide FOS of 5.

Investigation

Due to known conveyance collisions in other mines, which make use of rope guides, AATS carried out comprehensive testing and simulation for the Palabora shafts.

This started with wind tunnel tests on the production shaft skips to establish the lift coefficient. This coefficient was used to determine the side forces on the conveyance when travelling near to the shaft walls. A steady aerodynamic force was assumed. Buffeting forces were also determined to simulate the passing of skips in mid-shaft.

These parameters were then included in the analytical modelling of the shaft systems to verify the maximum displacements expected by the conveyances with various guide rope parameters. The lateral displacement of the conveyance plays a role in determining the required shaft diameter.

The nominal clearances in the shaft together with the predicted clearances due to deflection are illustrated in Figure 14.

The outer-limits

The production winders are operating at the outer limits of

Table III

Regulations for rope guide

	Guide rope FOS	Minimum clearance between conveyance and ...	
		conveyance	side wall
UK	5.0	930 mm	460 mm
Germany	4.5	500 mm	300 mm
Sweden		500 mm	250 mm
South Africa	6.0	-	-

Table IV

Deflection of skips for various forces

Force	Maximum lateral deflection of skips ...	
	ascending loaded	descending empty
Coriolis	63 mm	53 mm
Steady aerodynamic	30/26/19 mm	25/19 mm
Rope torque	4° (90 mm)	3.7° (82 mm)
Buffeting	2 mm	4 mm

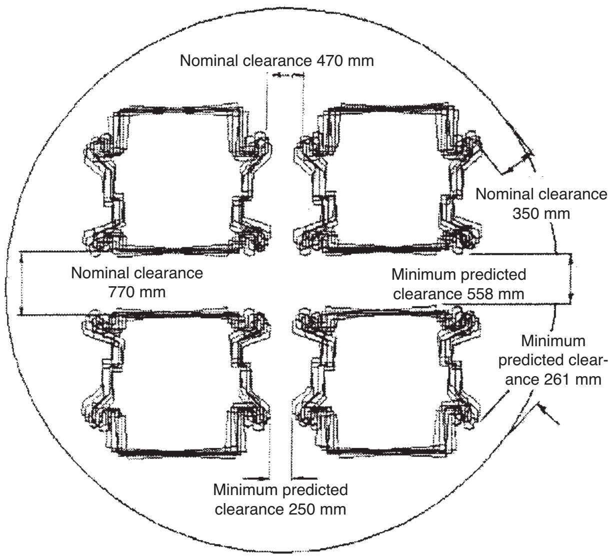

Figure 14—Assessing the clearances for the skips

mass, speed and depth, and hence are benchmarks for future development. This was achieved through intensive research, design and control.

The design of the headgear and shaft bottom has made provision for the installation of rubbing ropes between the skips to increase safety by ensuring that the displacements are constrained. These will most likely not be required or installed.

The rock winding control system also ensures that the skips depart at intervals so that the four skips do not pass each other simultaneously causing additional buffeting forces.

Rope tensioning

The guide ropes are tensioned hydraulically in the headgear and then anchored in the headgear and shaft bottom with conventional suspension glands. The ropes are tensioned to a minimum Factor of Safety of 5, based on the tensile strength of the ropes as legally prescribed. A 10% tension variance across opposite sides of each conveyance has been incorporated. This is purely based on historical practice and was incorporated as added assurance. From a scientific point of view, the benefit and necessity of this still requires conclusive evidence.

Currently extensive research is being conducted by AATS regarding the utilization of rope guides in shafts. Simulation models, using MATLAB and Simulink, have been developed and have been validated by means of empirical methods and tests conducted by the CSIR. A presentation by R.S. Hamilton, held at *Mine Hoisting 2000*, covers these aspects in greater detail.

Fixed guides

In order that the rope guides could be safely implemented in the service shaft it was necessary to install fixed guides for the man-material cage in such a way that the clearance between conveyances was not compromised.

The solution: Cantilevered stub-bunton shaft steelwork, connected to shaft sidewall by pivoted connections. However, it is vital that the conveyance cannot disengage from the guides and also not get snagged in the guides. Various factors dictated a cautious approach to the design of the Palabora service shaft steelwork.

- ➤ The extent to which man-material cage parameters (size, mass, payload and winding speed) affect the transferred loads, falls outside current experience.
- ➤ The shaft steelwork configuration is unique.
- ➤ The shaft steelwork connection details, including BOMs and Thread head fasteners, are unique.

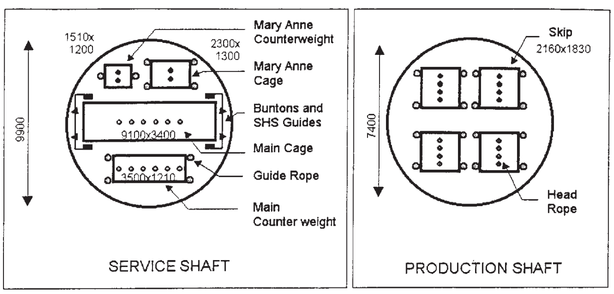

Figure 15—Shaft schematic: showing conveyances, ropes and guides

Design criteria

The following standards and references were used in the design process:

- ➤ COMRO user guide no. 21: Design guidelines for the dynamic performance of shaft steelwork and conveyances
- ➤ SABS 0208: Design of structures for the mining industry
  - Part 3: Conveyances
  - Part 4: Shaft system structures
- ➤ SABS 0162: The structural use of steel
- ➤ BS 7608: Fatigue design and assessment of steel structures.

Design process

The design was thereafter based on a fundamental understanding of the dynamic behaviour of conveyances and shaft steelwork. The design development underwent independent reviews and audits by third party consultants.

Once a design was proposed it underwent extensive testing to establish the integrity of the design. The test work included finite element analysis on the structure followed by dynamic load testing on a section of steelwork. These tests identified problem areas, assisted in modifying the design and finally demonstrated the structural integrity of the design.

The resulting design was made for optimum fatigue life and eliminated steelwork across the shaft.

Overwind and underwind protection devices

State of the art SELDA arrestors are used in the production and service shafts. These minimize the hazards associated with over-winds and hence enhance safety. They are the most comprehensive conveyance arresting installation in South Africa and considered to be the most reliable for Koepe winding.

They have significant advantages over other common arresting methods. The performance is predictable and not affected by the shaft conditions or contamination. They have constant rates of retardation and a long arresting distance. One significant benefit is that the SELDA units can quickly be re-commissioned after activation.

Alternative devices

The arresting device had to comply with the following requirements: In a worst case overwind—full speed (12m/s) for the service shaft conveyances and 2/3 speed (12m/s) for the production shaft skips—the arresting system should:

- ➤ Avoid major structural damage in the headgear and shaft bottom
- ➤ Prevent the head ropes from breaking
- ➤ Stop the conveyance before the crash beams
- ➤ Stop such that the deceleration rates are within human tolerance levels.

Various options were investigated including solid impact crash beams, gouging of timber beams, wedging system generating friction, viscous or visco-elastic buffers (JARRET or OLEO buffers) and SELDA arrestors.

After some consideration and elimination, an evaluation was conducted by AATS on the feasibility of a SELDA and

JARRET buffer combination and recommended that only SELDA arrestors be used. In order to achieve an acceptable stopping distance the JARRET buffers, which operate on a cylinder stroke, are excessively large and hence very expensive.

Strain energy linear ductile arrestor

The basic arrangement of the SELDA (Strain Energy Linear Ductile Arrestor) arrestors is shown in Figure 16.

In an overwind condition the conveyance engages with the arrestor frame. The SELDA boxes, attached to the frame, contain a number of steel rollers (Figure 17) into which the SELDA strips are installed. The SELDA strips are metal strips specifically selected for the required application. On impact, of the conveyance with the SELDA frame, these rollers force themselves over the SELDA strips. The process of plastically deforming the strips converts the kinetic energy to strain energy, providing deceleration of the conveyance.

Simulation

Computer simulation of the crash dynamics was performed to predict the peak rope tensions, conveyance deceleration and distance travelled.

The arrestors are arranged such that the conveyance travelling down is stopped just before the conveyance travelling up. This causes a drop in tension in the head rope and slippage on the drum reducing the hoisting force on the top conveyance.

The simulation results for the loaded man-material cage, ascending at 12m/s, are shown in Figure 18.

The SELDA specifications, including the lengths required, for the different conveyances are as follows in Table V.

The stopping distance travelled is 8.2 m over a time period of about 1.7 seconds. The maximum rope tension reaches a value of 34.6% of the breaking strength of the head rope.

Rock handling system

The extent of the holistic approach to the design and operation of the mine is evident in the rock handling system. The entire process is monitored and controlled via PLC to the central control room. The only operator interaction is through the transportation of the ore from the drawbells to the crushers by means of the LHDs. From there the system is automatically controlled with information from the instrumentation providing intelligent feedback to the central control room on surface. In order to ensure maximum efficiency with the usage of the LHDs specific instructions are relayed to the operators as to which tipping bays and access route to use.

Production winder duty cycle

The average hoisting capacity is 33 000 tons per day based on a 20 hour per day system availability—this includes a ten-per cent catch-up. However, the peak hoisting capacity identified by computer simulation is 37 500 tons per day, which caters for peaks anticipated in the mining rate.

The skips operate at 18m/s with acceleration and deceleration rates of 0.85m/s^2. The skip loading-tipping period is 16 seconds. The total cycle time is 229.6 seconds.

Skip loading

At the bottom of the production shaft, automatic loading with variable speed loading conveyors eliminates the use of loading flasks resulting in reduced spillage and minimizes impact damage to skips and ropes during the loading procedure. The use of loading conveyors also eliminates the need for large shaft station excavations where loading flasks would be positioned and reduced the shaft depth by about 15 m. This system was used successfully in the exploration shaft during the underground development phase of the project.

Two silos each with a live capacity of 2 500 tons store the ore after being transported via the 1 325 m incline conveyor

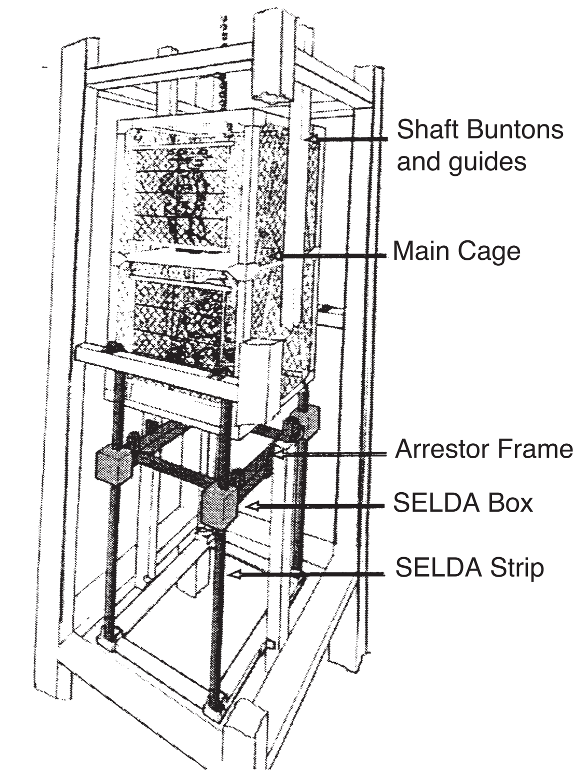

Figure 16—Conveyance using SELDA arrestors

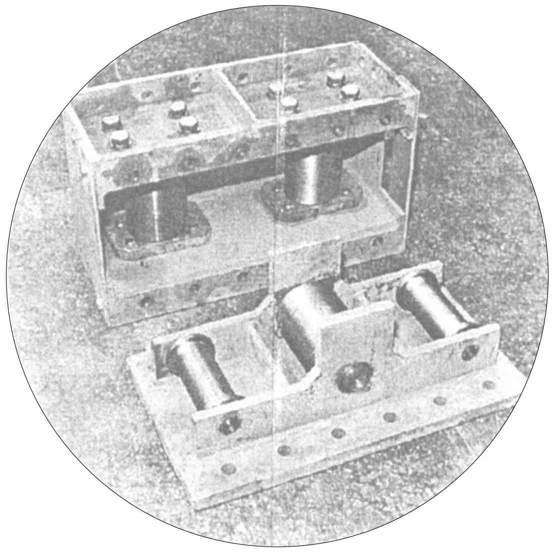

Figure 17—SELDA box construction

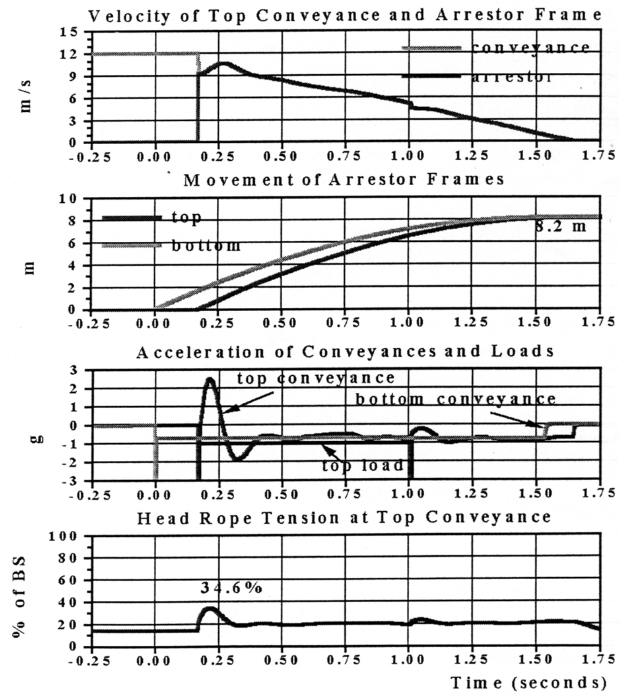

Figure 18—SELDA simulation results

Table V

SELDA specifications

Conveyance	SELDA details	
	Headgear	Shaft bottom
Skips	6 type E, 9.2 m	2 type E, 9.2 m
Man-material cage	6 type E, 8.8 m	4 type E, 6.4 m
Man-material counterweight	6 type E, 8.8 m	4 type E, 6.4 m
Mary Anne	2 type A, 9.8 m	2 type A, 6.9 m
M.A. counter-weight	2 type A, 9.8 m	2 type A, 6.9 m

from the crushers. These bins are fitted with radar level detection devices. Each silo can be discharged through two independently controlled variable vibrating feeders. The vibrating feeders discharge onto weighing conveyors, equipped with 'weightometers'. These in turn discharge onto 2100 mm wide loading conveyors initially travelling at 0.35m/s. All the conveyors are independently controlled and have variable speed drives together with position encoders. Once the loading (holding) conveyor has received 30 tons of ore the weighing conveyor stops. As soon as a skip is in the loading station, diverter cars move to 'in position' skip for filling and hoisting. The loading conveyor speeds up to 3.15m/s and discharges the payload into the skip in 14.6 seconds. Refer to Figure 19.

Skip tipping

As soon as the loaded skip approaches the headgear it slows to creep speed and is located into fixed guides. The door lock engages into a scroll, unlocking the door and simultaneously the body engages in the retracting mechanism. A hydraulic cylinder pulls the body of the skip out, about a pivot point so that the door is located over the storage bin. After the ore has discharged the skip body and door are returned to their normal operating position before the start of the next winding trip.

The ore is then transported via overhead conveyors to the surface stockpiles ready for processing in the plant.

Conclusion

The design of a 30 000 ton per day underground mine at Phalaborwa presented many and various challenges to the owner and the design team.

Using modern best and proven practice, innovative engineering, extensive test work and verification by world-wide experts these challenges were met head on and overcome. The state-of-the-art system will be in operation by the end of the year 2000.

The result: An engineering flagship of today and the future!

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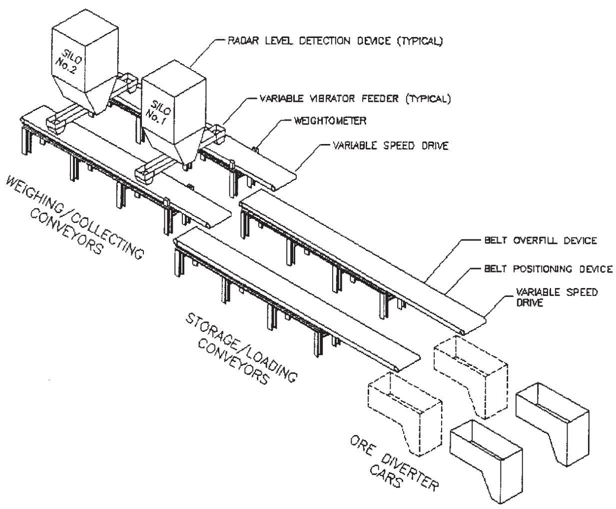

Figure 19—Simplified layout of automatic skip loading system

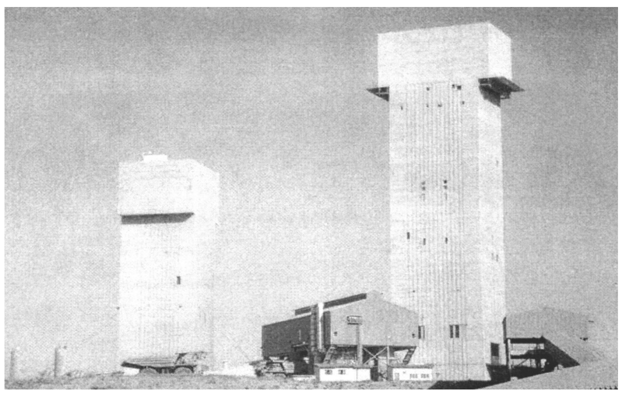

Figure 20—The Palabora underground mining project headgears