The Vaun self-climbing skip (SCS) system

by B. Kenealy*

Typical hoist system details

A typical deep shaft is President Steyn No. 2 in the Free State, where 9 tonnes of ore are hoisted at about 15 metres per second from 2378 metres below surface. The skips and attachments each weigh 7 tonnes and they are connected by 43 tonnes of rope, so that to hoist the 9 tonnes of payload, a total of 66 tonnes is accelerated from standstill to 55 km/h for each cycle, using an average of 3185 kilowatts of power in the process. The cycle time for the hoisting is 3.22 minutes. The peak power consumption is 6954 kilowatts, which determines the size of the motor used.

Is this the right approach? Are larger skips moving at higher speeds the answer? Is there another way?

A low speed alternative

In contrast to the high velocity approach is the Vaun self-climbing system. The same two compartments in a shaft are occupied, but instead of one skip plummeting down in the one compartment and the other rushing up in the second compartment, we have a number of Vaun skips quietly, slowly and steadily climbing up to surface, one behind the other in an orderly progression in one shaft compartment. In the other compartment the skips returning to the working levels move downward in the same orderly procession, but at higher speed, generating power as they go down.

Energy saving with the low speed system

It is interesting to compare the Vaun system power requirements with the rope hoist.

1) The average 3185 kW used at President Steyn to raise 9 tonnes could be used to raise 1217 tonnes at a steady 12 metres/minute, assuming 75% efficiency. This is the equivalent of 76 skips each of mass 16 tonnes with 9 tonnes payload. With the same power usage a slow hoisting system can lift 76 times the load!
2) At the 12 metre/minute speed a Vaun skip would move from the loading flask to the ore bin on surface in 3.3 hours, and to raise the same tonnage of ore per hour as the rope system (162 tonnes), we would need 18 skips arriving per hour, or a total of 60 skips climbing up in the shaft. Thus the power needed for a rope hoist will drive 76 Vaun skips, but only 60 are needed to do the same work! The Vaun skip has its on-board drive mechanism, so it is heavier than the conventional skip, but the increase is estimated to be only 3 tonnes, i.e. 19 vs 16 tonnes. The power to raise 60 Vaun skips of 19 tonnes, using 50 kW motors is 3000 kW, thus saving 5.8% on electrical energy on the journey to surface.
3) The skips descending into the mine from surface represent potential energy and the Vaun system recovers this as far as possible. The empty skips going down the shaft will return 662 kilowatts (after allowing very high transmission losses) to the system. This is a further 21.1% saving on the rope hoist, or a total saving of 26.9%. (The derivation of these figures is given in the Appendix.)

The energy savings available with the Vaun system are very large, but many other benefits are delivered by the system.

Mechanical features of Vaun self-climbing skips

It is now time to show you the basic mechanical features of the Vaun skip system, so that you may follow its features more easily when I discuss them (see Figures 1 and 2). The ore is carried in a conventional type of skip, which is carried on a cradle below the hoisting mechanism. The hoisting mechanism is in effect a mechanical copy of the ancient miner climbing up a shaft on a ladder, but it has three or more 'hands' instead of two, and it is tireless.

The drive is provided by a two-speed AC electric motor which drives a reduction gearbox, which in turn drives a set of three or more cams. These cams each control a 'hand' or ratchet, which starts a cycle holding onto a rung of the 'ladder' which is secured to the wall of the mineshaft. The cam moves the ratchet so that the skip as a whole is lifted upwards at a steady speed. When the ratchet has gone through most of its lift the second ratchet engages with the ladder and holds onto it, while the third ratchet, which had been holding onto the ladder now disengages and is raised rapidly by its cam to engage on another higher rung on the ladder. The first ratchet, still holding on and lifting, reaches the end of its travel and it disengages in turn. At all times at least two ratchets are engaged and holding onto the ladder, and so the skip is always securely suspended from the ladder. As the lifting motion of each ratchet is at the same speed and there are always two engaged, the upward motion of the skip is completely uniform, smooth and shockless.

The drive mechanism contains a second set of cams, these being designed for climbing down the shaft, and also for higher speed operation. The higher speed of descent is used to reduce the number of skips employed. In the

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* *Bergman-ingérop (Pty) Ltd, P.O. Box 3867, Rivonia 2128.*

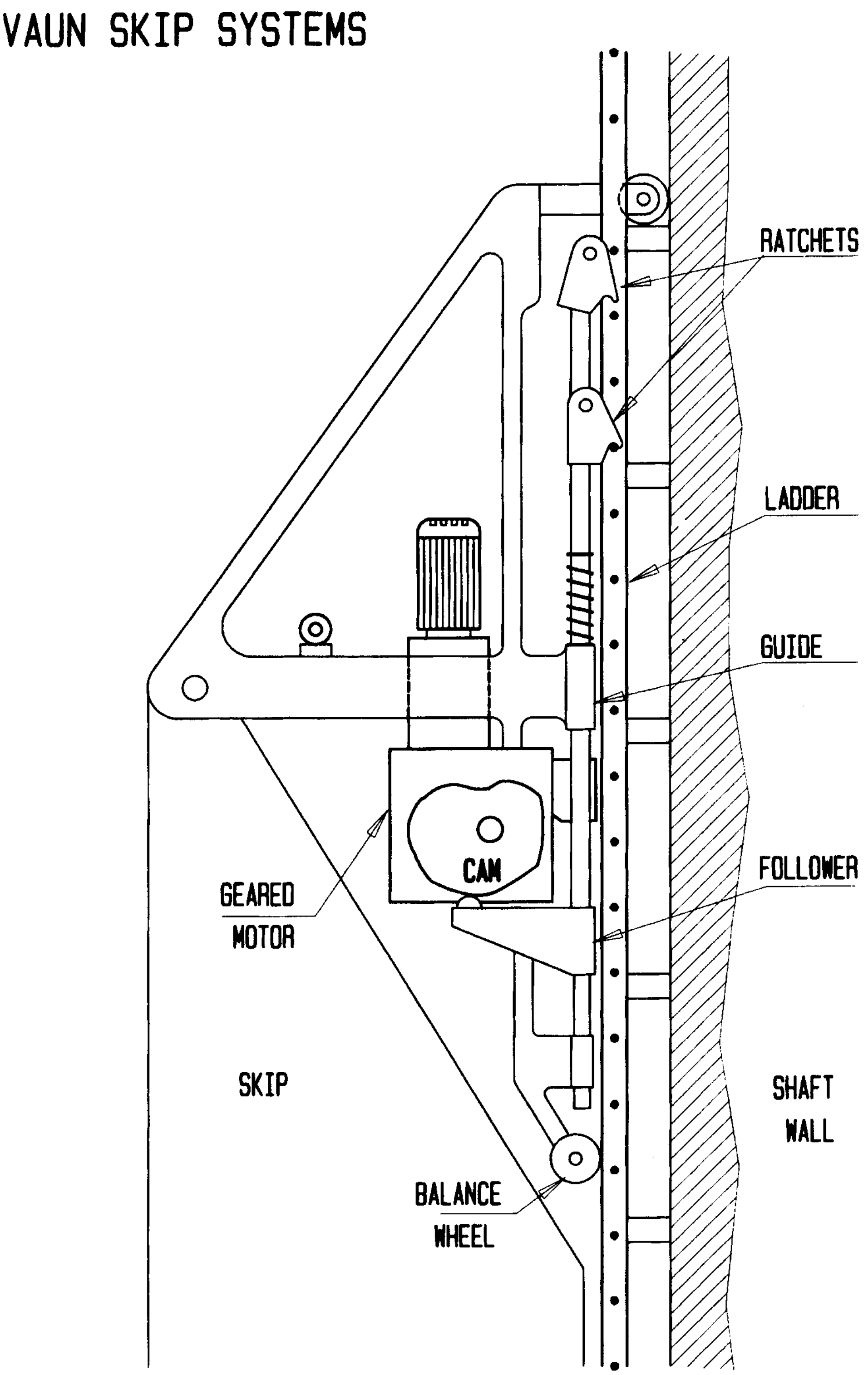
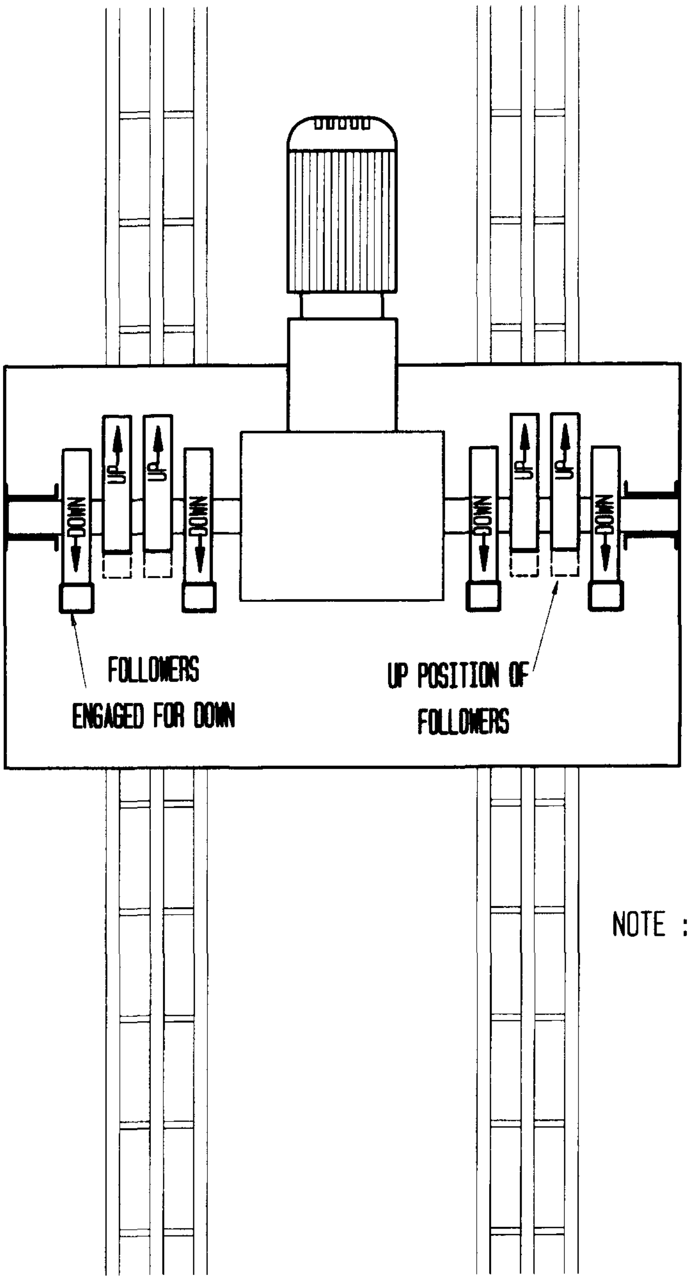


FIG. 1

GENERAL ARRANGEMENT OF VAUN SKIP

PATENT No 87/8511

VAUN SKIP SYSTEMS



NOTE :- RATCHET ARMS,
RATCHET RODS ETC.
NOT SHOWN FOR
CLARITY

PATENT No 87/9356
No 88/4630

FIG. 2

GENERAL ARRANGEMENT OF VAUN SKIP CAMS AND FOLLOWERS

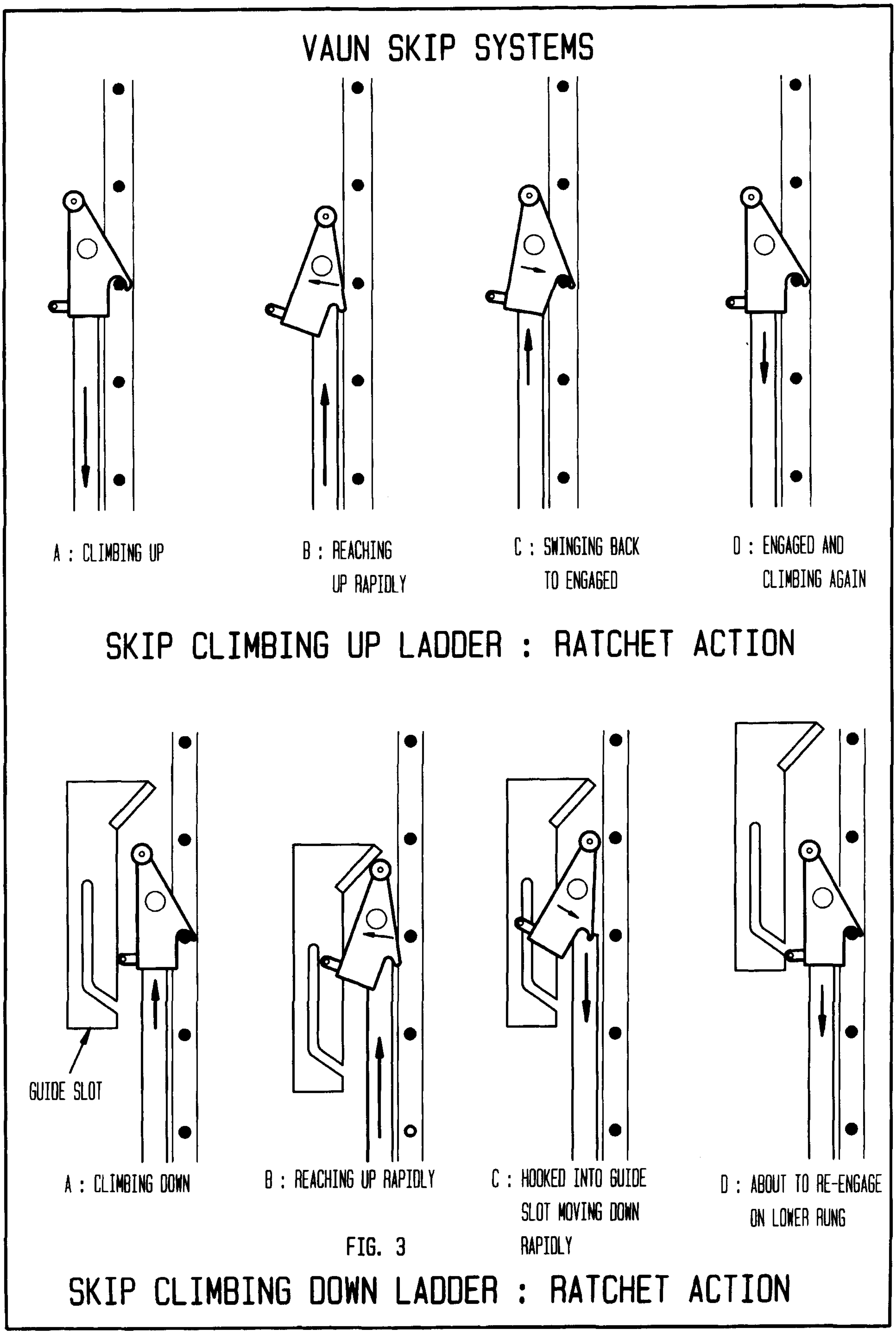

VAUN SKIP SYSTEMS
A : CLIMBING UP
B : REACHING UP RAPIDLY
C : SWINGING BACK TO ENGAGED
D : ENGAGED AND CLIMBING AGAIN
SKIP CLIMBING UP LADDER : RATCHET ACTION
GUIDE SLOT
A : CLIMBING DOWN
B : REACHING UP RAPIDLY
C : HOOKED INTO GUIDE SLOT MOVING DOWN RAPIDLY
D : ABOUT TO RE-ENGAGE ON LOWER RUNG
SKIP CLIMBING DOWN LADDER : RATCHET ACTION

FIG. 3

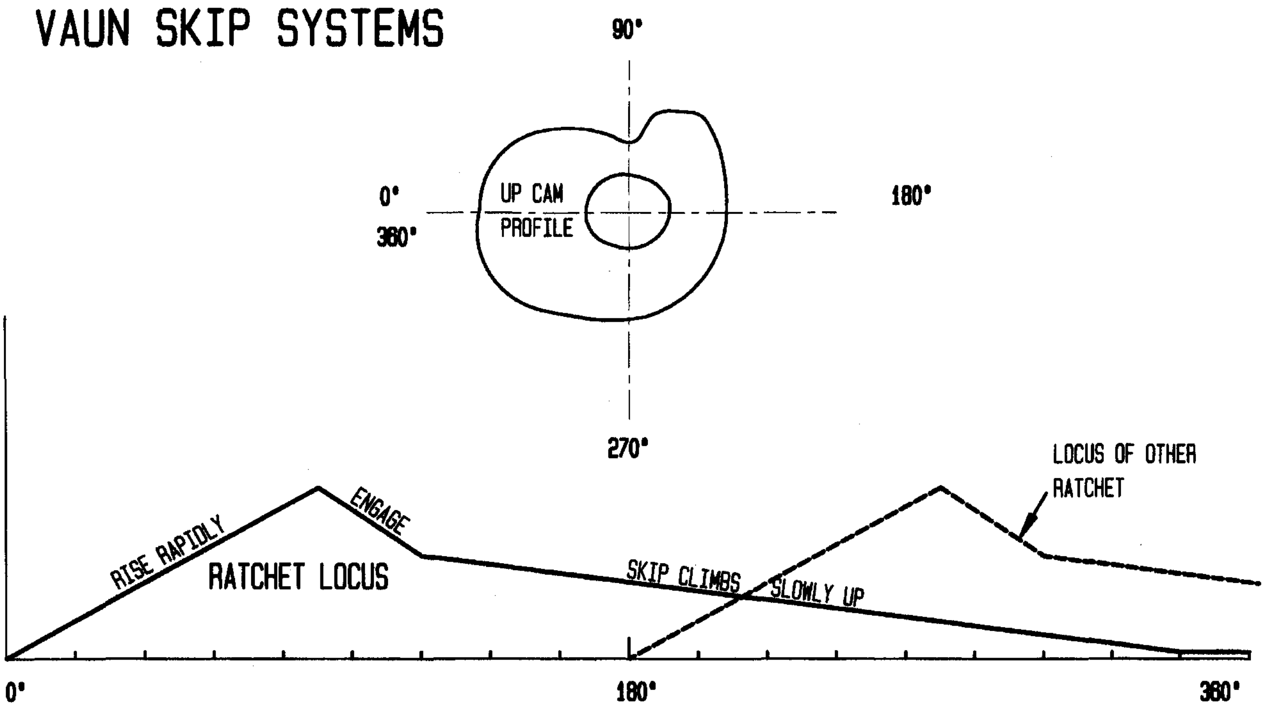


FIG. 4
CAM PROFILE FOR CLIMBING UP

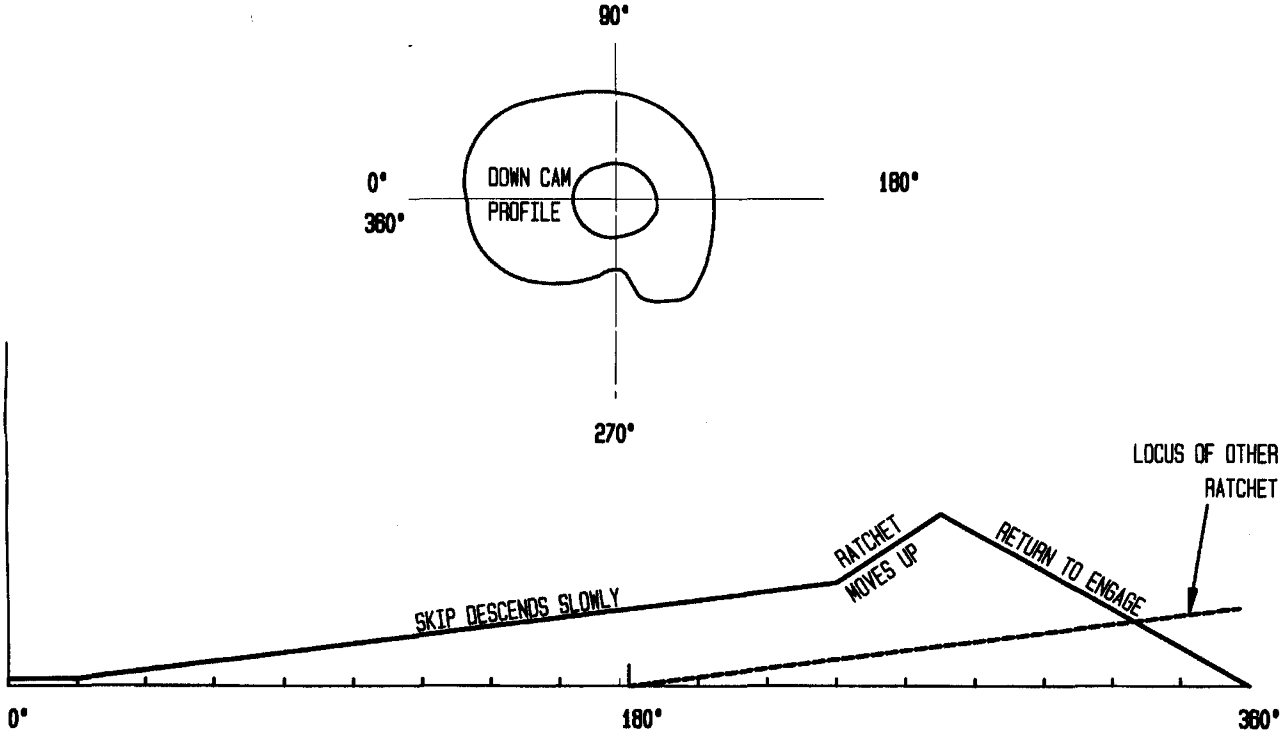


FIG. 5
CAM PROFILE FOR CLIMBING DOWN

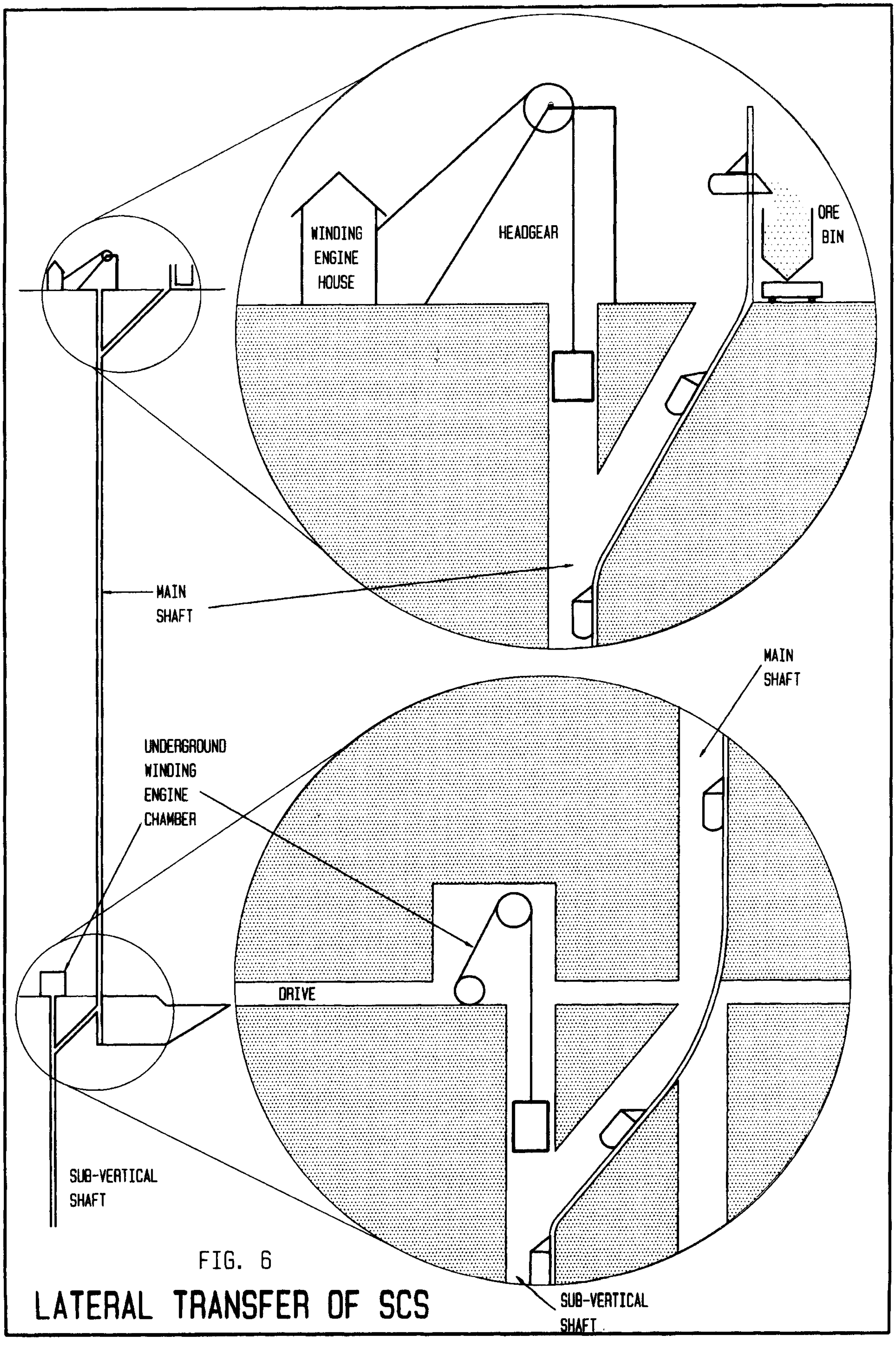


FIG. 6

LATERAL TRANSFER OF SCS

example only 20 skips are descending, at three times the ascending speed, i.e. 36 metres per minute. No power is used, in fact the motors are driven by the weight of the skip and actually generate power which is returned to the system to assist the skips climbing up.

Figure 3 shows the action of the ratchets in their two modes.

Minimum shock, smooth motion

The velocity of the skip is constant when out of the short acceleration period. Each cam is arranged to take over the load smoothly from the previous cam, both lifting together before the other releases its grip and rises rapidly to grasp another rung higher up. The cam profiles are shown in Figures 4 and 5.

Minimum wear

It is important to note that there is no relative motion between the bearing surface of the ratchet and the ladder rung, so there is no abrasive wear on either part. When the ratchet is moving up to grasp the next rung it makes contact on its sloping face with the lower side of the rung, but this occurs with no load on the parts and the forces are minimal, as will be the wear. When climbing down the spring-loaded hook which engages in the guide is a potential wear area, but this again works during an unloaded phase of the motion, so wear is minimised. These wearing surfaces would be hardened and replaceable. All other parts which have relative motion are lubricated and protected by seals or sleeves.

Safe, positive support on the ladder

At least two ratchets are always holding the skip at any time, and no forces acting horizontally or downwards can dislodge it. Only a force acting upwards can do this, and this is opposed by the mass of the skip. A seismic shock, should it act vertically, would have to be of very large amplitude to unhook all the ratchets from the ladder. The skip is thus secure against all normal forces which might act in the shaft, and if the power should fail, the climbing skips will slow to a halt, and then gently move back to a position where all the ratchets are holding onto their respective rungs. A skip climbing down would be rapidly brought to a halt by the built-in brake on the motor if any emergency developed.

Safety criteria are monitored

The status of all important equipment on the skip, such as the motor, gearbox, cams etc. will be monitored and the relevant information transferred to data transponders located every 12 metres in the shaft. The position and status of each skip is thus passed to the control room every minute, enabling appropriate action to be taken if a dangerous situation develops.

Manufacturing standardization and cost benefits

The Vaun skip is a mass-produced item, using standard items wherever possible, and is thus able to be made at a low specific cost, when compared with the rope hoisting equipment, which is purpose designed and made, and no two are alike. The cost-per-ton of such equipment will be much higher than a self-climbing skip.

Scheduled maintenance

The benefits of mass production and standardization are enormous, and the most important of these benefits is in maintenance. The skips will be maintained on a preventive basis in workshops on the surface, under clean and pleasant working conditions. Skips will be diverted on a regular schedule from the operating shaft to the workshop and thoroughly inspected and serviced. All wearing parts will be checked and replaced if at or near the condemning tolerance, all lubrication checked, topped up or replaced, as necessary, and any modifications required will be carried out. Each skip would thus be seen on a regular basis, say once per week. A history of each skip will enable the management to monitor trends and take action if a pattern which could lead to future operational difficulty is seen.

Breakdown procedures

In the event that a skip should stop while in the shaft, the supervisory system would halt all skip movements immediately. The disabled skip would then be reached using the hoist in an adjacent shaft compartment, and a "pony" skip moved onto the ladder above the disabled one and connected to it. The "pony" skip would then haul the disabled one to surface or to a point at which it could be removed from the ladder.

This emphasises the interdependance of the two systems of transport in the shaft. The traditional fast moving rope hoist will still be used, as the self-climbing skip is too slow for personnel transport and explosives etc. The two systems will be developed side by side in the shaft.

Major advances at the shaft collar

The self-climbing skip can negotiate curves, and this gives the possibility of improving safety and congestion at the shaft collar area. Vaun skips would be diverted out of the main shaft a short distance below surface, moving to an incline which would take them away from the headgear to an ore bin some distance away. This will improve safety at the headgear and give more space for safe and convenient loading of men and materials travelling on the rope hoist system.

The electrical collection system

The supply to and collection from skips of electrical power presented a problem. Power rail systems are available, but these give access from one side only for the power collector. This implied that there would have to be separate power rail systems for the up and down travel, which added a huge expense to the system. A special design of power collector system was thus necessary. This power rail system can have access from either side and will be located between the two ladder systems. Collectors for the up direction will work on the one side, drawing power, and the down direction collectors will feed power into the rails on the other side. The up and down collectors are arranged so as not to interfere and pass by each other easily.

The conductors of the power rail system are protected from dust and moisture in the shaft with elastomeric shields which are opened by the passage of the collectors. The collectors are flexibly connected to the skip body, and follow it closely, yet can accommodate minor deviations of the track or the skip ladder from the ideal straight line. As the skip moves up or down the collector thus continues to conduct power to it without interruption.

The industry can save 25% or more on energy for raising ore, 50% on shaft equipping and a further large amount of interest chargeable on development costs, if the State can put up a modest development budget to make the Vaun self-climbing skip a reality. Employment for hundreds of new skilled workers will be created as well.

To summarize, the Vaun SCS offers the following:

* No limit on the depth of operation
* 25% or more saving on energy
* Reduction in capital expenditure
* Reduction in interest charges
* The system is self-stopping - no runaways
* Simple mechanical equipment
* Many standard production components used
* Compatible with existing shaft systems
* Simple, well-proven electrical equipment
* Adaptable to increased or decreased production
* Skips are transferrable to other shafts or mines
* Standardized designs
* Easy recovery if a skip stops *en route*
* Foolproof interlocking for safety
* Slow, steady speed = minimum wear
* Short delivery time = maximum flexibility
* Maintenance on surface
* Tipping can be away from the shaft collar
* Provides added employment.

The development programme for the Vaun Skip will be undertaken with the guidance of the Mining and Mechanical Engineering faculties of the University of the Witwatersrand.

TECHNICAL APPENDIX

The following is a comparison between the rope hoisting of ore at President Steyn No. 2 Shaft in the Free State with the equivalent Vaun self-climbing skip:

Pres. Steyn:	Mass of ore:	9 tonnes
	Velocity:	15 m/sec
	Maximum power:	6954 kw
	Average power:	3185 kw
	Mass of skip:	7 tonnes
	Mass of rope:	43 tonnes (Both skips)
	Shaft depth:	2378 meters
	Cycle time:	3.22 minutes
	Hoists per hour:	18.

1) Compare the average rope hoist power with Vaun skips raising ore at 0.2 metres/second:

Average power used in rope hoisting = 3185 kw
= 3185 x 101.974 kgf.m/sec
= 324,787 kgf.m/sec.

At 0.2 metres/sec and with efficiency of 75%, we will have:

$$\text{Tonnes lifted} = \frac{324.787 \times 0.75}{0.2 \times 1000} = 1217.95 \text{ tonnes.}$$

The existing skip has a mass of 16 tonnes (9 tonnes payload and 7 tonnes skip), and so at the slower speed we can raise, for the same power input:

$$\frac{1217.95}{16} = 76.12 \text{ conveyances of } 16 \text{ tonnes each.}$$

2) Calculate the number of Vaun skips needed to raise the same quantity of ore:

Ore raised per hour at Pres. Steyn:

18 x 9 tonnes = 162 tonnes.

Climbing time for Vaun skip at 0.2 metres/second:

$$\frac{2378}{0.2 \times 60 \times 60} = 3.30 \text{ hours.}$$

At 3.3 hours, to deliver 18 skips at the top of the shaft every hour, we require:

18 x 3.30 skips = 59.45 skips (say 60 skips).

The figure derived above refers to the number of skips climbing up the shaft only. The number of skips descending in the shaft has to be added to this, plus a number of skips under maintenance or repair to determine the full skip complement.

3) Power requirement for self-climbing skips:

If we assume a 75% mechanical efficiency, a mass of 19 tonnes (9 payload + 7 skip mass + 3 mechanical equipment) and a climbing speed of 0.2 metres/second, we have a power requirement of:

$$\frac{19.000 \times 0.2}{0.75 \times 101.974} = 49.69 \text{ kw.}$$

Rounding this to 50 kw, we have a total power requirement of:

60 skips x 50 kw = 3000 kw.

This is a power saving of 185 kw on the 3185 kw average power needed to hoist by rope from the same depth = 5.81 %.

4) The skips returning underground from surface have a mass of 10 tonnes, (7 tonnes skip + 3 tonnes mechanicals). The speed of descent should be faster than climbing, to reduce the number of skips and to use the full power rating of the motor to generate power from the potential energy in the mass of the skip. The motor is rated at 50 kw and the mechanical efficiency of the drive train is 75%. If we obtain the full 50 kw from the motor, the input from the skip must be:

$$\frac{50 \text{ kw}}{0.75} = 66.67 \text{ kw input from skip}$$

66.67 kw = 66.67 x 101.974 kgf.m/sec.

The speed of descent to give this power input will be:

$$\frac{66.67 \times 101.974}{10{,}000} = 0.679 \text{ metres / second.}$$

A speed of 0.679 metres per second is about 3.3 times the ascending speed of 0.2 metres per second.

If we use a two-speed motor with a 6 pole arrangement to climb (i.e. 970 rpm motor speed allowing 3% slip) and a 2 pole arrangement for descent (i.e. 3090 rpm speed allowing 3% slip), then we can expect a descending speed of:

Descending Speed

$$0.2 \text{ metres / second } \times \frac{3090}{1030} = 0.6 \text{ metres / second.}$$

The descending speed will thus be slightly less than the ideal to develop the full available power from the motor, and this power will be:

$$50 \times \frac{0.6}{0.679} = 44.18 \text{ kw.}$$

5) The number of skips descending will be one-third of those climbing up, i.e. 20, and the power they will push back into the system (at 75% efficiency, to cater for transmission losses) will be:

$$20 \times 44.18 \times 0.75 = 662.7 \text{ kw.}$$

This is an energy saving, compared with the rope hoisting scenario, of:

$$\frac{662.7 \times 100}{3185} = 21.1\%.$$

The total energy saving due to the Vaun skip system is thus:

$$21.1 + 5.8 = 26.9\%.$$

6) The headway, or distance between skips, in the scenario above will be:

$$\text{Ascending skips: } \frac{2378}{60} = 39.6 \text{ metres,}$$

$$\text{Descending skips: } \frac{2378}{20} = 118.9 \text{ metres.}$$

If there was a 1% difference in climbing speed, i.e. skip No.1 climbed at 12 metres/minute and skip No.2 climbed at 12.12 metres/minute, the 'catch-up' time to reduce the headway to zero would be:

$$\frac{39.6}{0.12} = 330 \text{ minutes} = 5.5 \text{ hours.}$$

As the climbing time is 3.3 hours, the headway would be reduced from about 40 metres to about 16 metres. The possibility of one skip colliding with another above it is thus not a significant factor, as motor speeds generally do not differ more than 1% for the same duty. ◆

Aid for small diamond diggers

As part of its commitment to assisting small, medium, and macro enterprises (SMMEs) in the minerals sector, Mintek is investigating ways of helping small diamond-mining operators.

In support of these operations, it will be offering small diamond miners the use of a portable diamond-panning pilot plant to optimize their recovery rates. A further form of assistance is the provision of (Mintek-manufactured) density beads, which are used to show the effectiveness of the miners' dense-medium separation activities, thereby enhancing the efficiency of their panning operations.

On a recent visit to a number of small operations along the Vaal River (near Barkly West), Mintek's Rob Guest and Jou Loo were impressed that many of the 'little guys' seemed more aware of the environment than some of their larger neighbours. 'The diggers separate out rocks and pebbles, which are used to build walls around the areas already excavated, and tailings are placed in these dams. Topsoil is then shovelled back on top, completing the operation in an environmentally friendly manner. This compares favourably with the many 'moonscape' dumps left behind both by diggers of yore and by some more modern medium-sized operations', says Rob Guest.

The African United Small Mining Association is also encouraging its members (who are often one-man operators working areas of 30 m x 30 m) to form larger groups of up to ten diggers, to enable them to enhance their buying power for earth-moving equipment and panning plants since, by moving more diamond-bearing gravels, they significantly increase their chances of recovery. ◆

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Stope support design methodology

The CSIR: Mining Technology has defined a methodology by which a stope support system may be designed, and then evaluated in order to determine how efficiently it would behave under either rockfall or rockburst conditions. The database used contains 12,000 fatalities and, because it is so big, for the first time reef specific criteria can be stated.

This technique will eventually lead to a computer program enabling mines to design stope support. As most people are in the stope(s), this will lead to increased safety in the stope(s), as well as cost savings for the mines through the design of the optimal support system for that particular stope.

In South African mines with tabular ore bodies, the design of stope support systems has in most cases been based on experience, past practices and cost considerations. Approximately 130 support systems have been identified in current use in industry. These include various support unit types with variations in spacing and support dimensions. Clearly, only a number of these systems are optimised with the rest being either over- or under-designed.

Variables were considered to evaluate a stope support system, i.e. force – deformation behaviour of the support units which constitute the stope support system, mining height, stope closure rate, stope closure during rockbursts and the associated velocity of closure (dynamic closure), spacing of stope support units, support resistance generated by the stope support system and the ability of the support system to absorb energy.

An analysis of the thickness of fall of ground and rockburst ejection was then undertaken for the Vaal Reef, the Ventersdorp Contact Reef and the Carbon Leader Reef. The intention is that any support system design or existing support system would need to be evaluated against these criteria. A similar process was undertaken to determine criteria for the support of stope gullies for these three reefs. This was done by measuring fallout thicknesses directly underground.

Further information: Mike Roberts (011) 358-0168, e-mail: mroberts@.csir.co.za ◆

Rockbreaking techniques key to survival

The number of advances in the development of rockbreaking processes and rockbreaking systems, has led the CSIR: Mining Technology to categorize these developments, thereby offering the mining industry an accurate evaluation of these systems, allowing them to select the best system(s) suited to their particular circumstances.

New rockbreaking processes and systems can form the basis of the new mining systems of the future which could significantly contribute to the South African gold and platinum mining industry, which urgently needs a technological breakthrough in stoping and development methods to remain competitive.

The innovative application of new and existing rockbreaking technologies would revolutionize mining methods, making them safer and more profitable, just as the worldwide trend to mechanize mining operations had as its major stimulus improved safety and mining operations in the face of rising labour costs.

While South Africa generally followed this trend in coal and base metal mining operations, in its unique precious metal industry mechanization has met with only limited success. Reasons for this are the very adverse conditions underground mitigating against mechanization — narrow, dipping reefs, hard, highly abrasive rock types; deep, extensive mines; highly stressed, seismically active ground conditions, a poor environment and a largely unskilled labour force. South Africa's gold and platinum mines' stoping operations have, therefore, remained the same for many decades, based on the drill-blast-clean-support cycle.

The design and operation of a face mining system is influenced by the rockbreaking method, the rock handling system, the support methodology, the materials handling system, the environmental control approach and the entire plethora of support systems. However, rockbreaking is the fundamental mining operation and can have a major effect on all the other parameters.

Further information: Rod Pickering (011) 358-0157 e-mail: rpicker@csir.co.za ◆

Quiet rockdrilling system

The pneumatically powered rockdrill used almost exclusively on South African gold mines emits approximately 111 dBA when running but not drilling, and 114 dBA when drilling. This latter equates to less than 30 seconds exposure to the noise per working day, without hearing protection, to ensure no long-term hearing loss.

The CSIR: Mining Technology took the opinion, as expressed by the US Bureau of Mines, that only by encasing the entire drill and steel in an air-tight bag would significant reductions in noise levels be possible. The concept involves a novel yet practical method of encasing the rock drill and drill steel (each of which currently contributes equally to the overall noise emission when drilling) in a sound deadening enclosure, controlling the exhaust air flow to reduce noise and adding sound deadening material as necessary, e.g. to the drill steel. To enable the system to drill in the stope, an integral stinger assembly will be included in future designs and an automatic drill retraction valve will be added, both of which will reduce the operator's involvement with his machine and thereby further improve his working conditions.

A laboratory version of the drilling system has been produced and evaluated; initial indications are that, without the addition of special sound deadening materials, the noise emission during over travel operation has been reduced from 111 to 87 dBA (256 fold reduction in noise power emission) and whilst drilling from 114 to 96 dBA (64 fold reduction in noise power emission).

Further information: George Harper: (011) 358-0084, e-mail: gharper@.csir.co.za ◆