AN OVERVIEW OF THE INSTALLATION OF THE FIRST MAN-RIDING BELT CONVEYOR IN A SOUTH AFRICAN GOLD MINE.

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INTRODUCTION

The installation of an underground inclined belt conveyor, designed for the raising of rock and the two-way transportation of men, has generated great interest in the South African Gold Mining Industry.

A Code of Practice issued by the South African Bureau of Standards clearly specifies the operational and design requirements for man riding conveyors. This paper examines aspects not covered by the code of practice, and provides guidelines on the practical implementation of a man riding conveyor system.

Although not the first man riding conveyor to be commissioned in South Africa, it is the first that was specifically designed for conveying run-of-mine rock and for the transportation of people on both the top and bottom belts. Important aspects covered in the paper include mechanical and electrical design, ergonomics and operational procedures, risk analysis, safety, and acceptance by the workforce.

PROLOGUE

Manriding of belt conveyers had never been officially sanctioned in South Africa until the commissioning of the first manriding conveyor at Tshikondeni Coal Mine in 1993. This 700m, 2.5m/s conveyor was installed in an 8 degree roadway to surface. Following the successful installation at Tshikondeni, a 200m, 1.5m/s conveyor situated in a 16 degree incline at Lavino Chrome Mine was converted for man-riding.

In 1994 Target Exploration Company Ltd. commenced development of an underground drilling platform 2 000 metres below surface, to explore ore bodies adjacent to the northwest border of Loraine Gold Mine, in the Free State. The drilling platform consisted of two 2km long declines, 30m apart, with interconnecting crosscuts at 100m intervals.

The twin declines were designed to provide 60m^3/s of ventilation air to the workings down a 5.5m by 3.8m high intake airway and a 4m by 3.8m return airway. A belt conveyor system was chosen for the removal of waste development rock, and for transporting the ore from the future mining operation. The 8.5 degree declines, and anticipated ore body configuration, suited the use of trackless equipment. The intake airway was therefore used to provide a 3.5m wide access roadway, adjacent to a 900mm wide belt conveyor.

The Target Project philosophy was to operate an efficient, highly mechanized mine in an environment conducive to maximizing the full potential of its highly skilled personnel. The operation would require a relatively small labour force, and therefore ergonomic considerations became an important aspect of machinery and equipment design. Access to the declines is down Loraine Gold Mine's No. 1 Shaft, along a 2km tramming haulage, down a sub-vertical shaft, and along a further 2km haulage. The total travelling distance from surface to the workings would be 8km, therefore transportation systems had to be made available to enable personnel to reach their place of work quickly and safely.

A study into the feasibility of using the decline belt conveyor for the transportation of people showed that a nominal shift size of one hundred people could be transported over the 2km distance, in between twenty to thirty minutes. To transport the same number of people along the roadway would require a fleet of five personnel carriers, and would take fifty percent longer.

It was therefore decided to maximize the benefit of the belt conveyor by designing it for the conveyance of persons in both directions, utilizing both the top and bottom belts. A meeting was then held with the Regional Director at the Department of Mineral and Energy to discuss the proposed conveyor design, and the safety issues associated with man-riding.

DESIGN AND COSTING

The initial design was for a 1 800m conveyor at an angle of 8.5 degrees, running at a speed of 2.5m/s. This necessitated the use of a steel cord belt of class ST1250F. Flame retardant belt was chosen to minimize the risk both to equipment, and to people working in the single ventilation intake airway.

DESCRIPTION	DATA
Length; Lift; Gradient; Speed	1 800m; 266m; 8.5 degrees; 2.5m/s
Belt width; Type; Covers	900mm; ST1250 F (fire retardant); 8 x 5
Material duty.	Waste rock and gold ore at 225 tons/hr (3.75 tons/min)
Men duty (top and bottom belts).	30 persons/min (2.25 tons/min based on 75kg/person at 5m intervals).
Motor & gearbox	Two 160kW, 525V AC induction motors, through 26:1 reducers.
Drive configuration	Tandem drives, shaft mounted on return pulley.
Brakes	Two electro-hydraulic brakes with 800mm diameter disc.
Pulleys	Lagged, crowned at edges.
Electrical control	Twin 525V variable speed thyristor convertor drives with vector controlled IGBT's.
Take-up and tensioning	Sinking: Winch take-up at top end. Permanent: Gravity tower take-up at tail end.
Idler configuration, top	3 roll, 35° trough, series 25, 127mm diameter, spaced at 2m.
Idler configuration, bottom	2 roll, 10° V return, 127mm diameter, spaced at 2m.

TABLE 1. Belt Conveyor Specification for Rock and Man Riding Duty.

The conveyor was to be installed adjacent to a roadway in the intake decline, and had to be operated and extended concurrently with development, at a rate of 100m per month. The design therefore had to facilitate extensions to the steelwork, provide adequate facilities for splicing of the belt, and cater for the erratic nature of the rock loads expected from the development end.

A winch take-up system was installed on the slack side of the return belt drive pulley, near the conveyor head end. This reduced production delays while extending the conveyor, by minimizing the amount of steelwork to be extended at the tail end. Upon completion of the decline development, a gravity take-up tower and trolley near the tail end replaced the winch arrangement.

A specially prepared section of the conveyor was made available for splicing, near the top of the decline. By removing the lower stringer, the 2m diameter, 200m length of belt could be spliced in a reasonably clean environment, and then fed down the decline.

The risk of belt tear was considered to be high during the development phase, and the method chosen for rip detection was the embedded loop system. A sensor at the loading box detects a healthy loop installed in the belt every 25m. If a longitudinal tear occurs, the loop is broken and the detector trips the conveyor belt.

A variable speed drive was chosen to facilitate the monthly belt installations, and as a contingency in the event that riding the belt at 2.5m/s would be unacceptable.

Once the design for the production requirements had been completed, the requirements for man riding had to be determined. Information gleaned from the Tshikondeni experience [1], and a visit to the mine to see the conveyor in operation, assisted in this. The Department of Mineral and Energy had drawn up draft regulations for the riding of conveyors, and this document influenced the safety provisions and dimensional details of the conveyor design. To enable man-riding on the lower belt, a clearance of 1.5m was provided along the entire length of the conveyor. The additional stringers, and 2.5m long conveyor legs, added a significant component to the overall cost. Despite the extra cost (summarized in Table 2), the concept of transporting men by belt conveyor was considered more economical than other alternatives.

DESCRIPTION	COST (Rands)	MAN-RIDING COMPONENT
Conveyor structure		
Head & tail, take-up, screens, general steelwork, & fixings. Weight: 41t.	260 000	
Platforms at each end. Weight: 5t.	58 000	58 000
8m stringers, and legs @ 4m. (1 800m x 4). Weight: 143t.	753 000	250 000
Concrete pedestals. Qty: 245	20 000	
Mechanical equipment		
Drives	179 000	
Brake	35 000	35 000
Holdback	29 000	
Take-up winch	89 000	
Head, drive, snub, tail & take-up pulleys.	102 000	
35 degree carrying & impact idlers, and fixings. Qty: 1 000	222 000	
10 degree return idlers. Qty: 900.	135 000	45 000
Control and monitoring		
Variable speed control	126 000	30 000
Safety and control cubicle with SCADA system.	80 000	
Belt misalignment, belt slip & blocked chute detection.	29 000	10 000
Cabling.	37 000	
Miscellaneous		
Bottom belt pull-keys with speech communication.	20 000	10 000
Top belt pull-keys.	10 000	10 000
Man riding safety gates, trips, indicators, PLC, signs, and lighting.	54 000	54 000
Man plough.	2 000	2 000
Pigtail eyebolts.	4 000	2 000
Belt and belt rip detection		
4 000m fire retardant ST1250 belting with embedded loops for rip detection.	2 000 000	
Total:	4 244 000	506 000

TABLE 2. Cost Breakdown for a 1.8km Man Riding Belt Conveyor.

IMPLEMENTATION

By 1995 the decline development was well under way. However diamond drilling had revealed unforeseen geological features, which meant it was no longer viable to develop the decline to its originally planned length of 2km. It was proposed to develop three declines in a dog-leg configuration, and three conveyors were subsequently planned, of 890m, 250m and 1 400m lengths. This allowed the first conveyor to be commissioned in its permanent man-riding configuration sooner than expected.

Early in 1996, a Code of Practice for man riding conveyors [2] was issued by the South African Bureau of Standards, and this necessitated some minor changes to the man-riding conveyor design. In June 1996 the Regional Mining Engineer passed the conveyor for man-riding in terms of the requirements of the Code of Practice.

Subsequently, the 250m conveyor in the second decline was commissioned early in 1997, and a 600m stretch of the conveyor in the third decline commissioned in June 1997. The variable speed drive on the first conveyor was replaced by a single, direct-on start, 160kW drive with fluid coupling, and a gravity take-up installed near the tail end. The variable speed drive and take-up winch were then transferred for use on the third conveyor.

RECOMMENDED MAN RIDING EQUIPMENT AND SYSTEMS

In addition to the equipment normally found on an underground belt conveyor, certain features should be incorporated into a man-riding conveyor design to ensure maximum safety and ease of use.

Many of these features are specified in detail in the SABS code of practice. Others have been found to be necessary, or desirable, from practical experience. Figure 1 illustrates a typical boarding and alighting arrangement near a conveyor head end. This area requires the most planning and attention to detail in order to avoid congestion and interference with other activities in the vicinity.

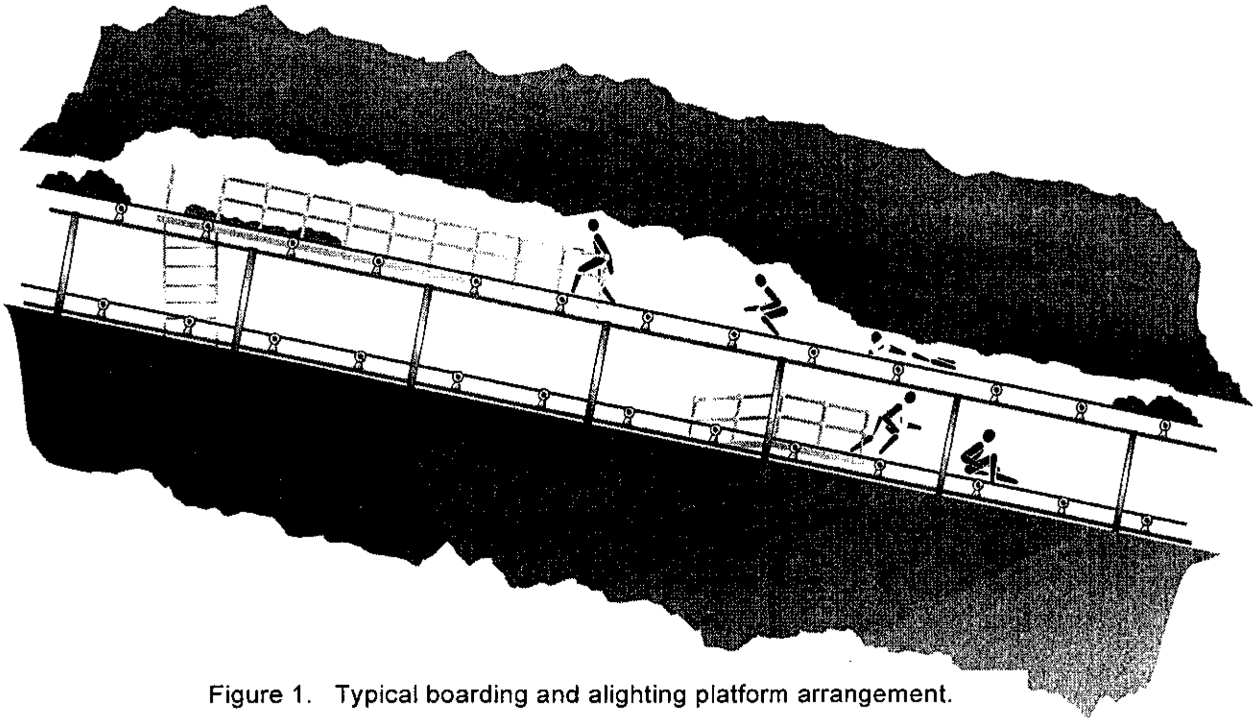

Figure 1. Typical boarding and alighting platform arrangement.

The following list includes some of the requirements of the SABS code of practice, but is not exhaustive. The relevant section of the code of practice is given for reference purposes.

- Boarding and alighting platforms. (Sections 7 & 8).
- Safety barriers at boarding and alighting platforms (Figure 2).
- Special stringer arrangement at lower belt alighting platform (Figure 3).
- Additional clearance above belts. (Section 5).
- Some additional sliping of the hanging wall and sidewall around the platform areas, to provide adequate clearances for riders. (Section 5).
- A "man plough" before the tail pulley. (Section 10.1).
- An additional trip wire along the length of the conveyor. (Section 10.8).
- A brake to prevent runaway, and to stop within 9m (Section 6).
- Audio communication at each pull key. (Section 11.1)
- Belt slip detectors. (Section 10.4)
- Belt rip detectors. (See section 6).
- Belt training idlers near platforms, and other areas as required. (Section 10.5).
- Belt misalignment detectors. (Section 10.5).
- "Over-travel" trips beyond each alighting platform. (Section 10.1).
- "Wake-up" chains across belt at alighting platform.
- Chute blockage trips. (Section 10.6).
- Additional lights, alarms, signals and notices at boarding and alighting platforms. (Section 9).
- 10 degree V-return idlers, spaced at 2m intervals, instead of flat rolls.
- Intermediate ladders for disembarkation from the top belt after a stoppage.

Novice riders experience most difficulty boarding and alighting from the belt. Often they lose their balance at this point, and therefore it is recommended that a sheet of conveyor belt is suspended vertically along the opposite length of the conveyor to the platforms, and for a distance of four metres beyond, to act as a safety barrier (Fig. 2).

At the bottom belt alighting station, a modified stringer support and idler frame is recommended, to provide maximum head clearance for riders as they step onto the platform (Fig. 3). A narrow alighting platform also assists riders to quickly reach the handrail for support as they step onto the platform.

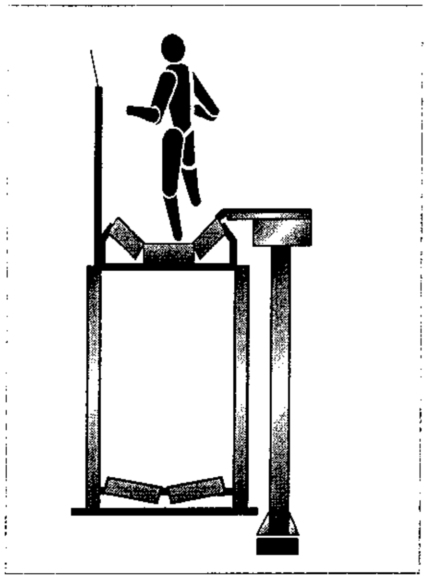

Figure 2. Safety barrier opposite platform.

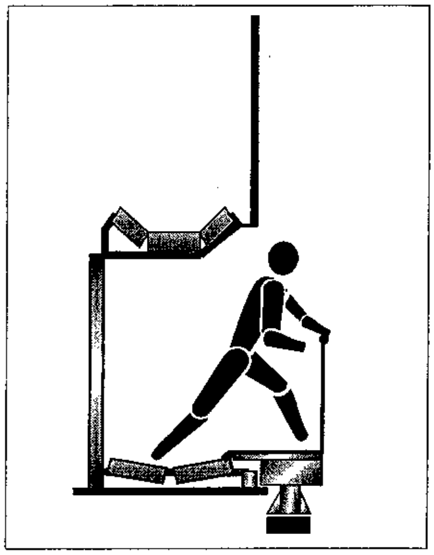

Figure 3. Modified stringer support.

A clearance above the belt of at least 1.1m allows riders to sit comfortably for the duration of the ride. If a clearance of 1.6m can be maintained along the length of the belt, then additional alighting platforms can be retrofitted without having to modify the conveyor structure.

A boarding platform mounted *over* the lower belt instead of alongside it was found to be very successful. This avoided the need to take up valuable space in the adjacent roadway.

A brake is necessary on an inclined conveyor to prevent runaway in the event of the bottom belt being fully loaded with riders while the top belt is empty, and to ensure that the conveyor stops within 9m after an emergency trip-out.

Over-travel limit switches are fitted to safety gates beyond the alighting platforms. However, as riding may take place simultaneously to conveying rock, the gates cannot be set close enough to the belt to detect a prostrate rider. "Wake-up" chains can be hung over the belt, below the level of the rock, at a point half way along the length of the alighting platform. These normally encourage the most enervated rider to hastily alight, thus preventing a much ruder awakening further along the belt.

Ladders can be installed at suitable intervals along the length of the belt to assist riders to disembark from the top belt after a conveyor stoppage. These can also be of assistance to maintenance personnel.

RISK ANALYSIS

Some of the areas to be addressed when considering man-riding on belt conveyors, are as follows.

- Acceptance by the work force, by management, by the inspectorate.
- Training facilities.
- Misuse of the system (illegal boarding and alighting of the belt).
- Emergency procedures.
- Risks associated with adjacent roadway.
- Fire risk.
- Maintenance & supervision.
- Belt breakage.

The choice of a variable speed drive not only allows for gradual start-up of a fully loaded belt, but also enables the top speed of the belt to be reduced if it is found unacceptable to the riders. The minimum clearances recommended by the code of practice were exceeded sufficiently to facilitate easy boarding and alighting, and to allow for a comfortable ride. Ride comfort was also improved by the use of a steel cord belt, and by installing V-return idlers. The work force generally welcomed the belt riding facility, and no major problems have yet been encountered in its acceptance.

Man riding procedures were compiled in consultation with the work force, and meetings held to discuss safe and acceptable boarding and alighting techniques. The design and position of the platforms and handrails were subsequently finalized following these discussions.

The requirement for riders to alight from the belt in the event of a trip-out was considered safer than expecting them to wait for the belt to be re-started. Ladders for disembarking from the top belt were provided at 100m intervals.

The risk of fire was minimized through the choice of fire retardant belt, and the installation of fire hoses at regular intervals. The use of HDPE lined rollers has been considered to reduce maintenance costs, but the advantage, compared to the potential fire hazard, is currently under investigation.

The risk of belt breakage should be considered in relation to the operational characteristics of the conveyor system. Belt arresting systems are available, but should be carefully considered against the option of controlling the risk through adequate design, proper maintenance, and management control.

Effective training facilities can be expensive to implement, but need to be considered against the practicalities of effective training in-situ underground. The most effective training was found to be practicing on an operating belt, under controlled and supervised conditions. This was not always possible in the underground situation, and was often rushed, thus increasing the risk of accidents. Experience showed that novice riders were most prone to accidents, and it was decided to commission a training belt on surface, utilizing a stretch of the surface waste rock conveyor.

TRAINING AND USE

The initial training procedure for novices entailed the use of a length of belt towed behind a vehicle on surface, onto which the trainee would then jump on and off to acquire a sense of speed and balance.

In practice, the rider's feet tend to be swept away from under him if an attempt is made to board the belt whilst trying to maintain his balance. The safest boarding method is for the rider to throw himself forward onto the belt, with the emphasis being on keeping the body weight forward.

Training on surface includes knowledge of the procedures required for riding the conveyor belt. These procedures are displayed at each man-riding station.

CONVEYOR BELT MAN-RIDING PROCEDURES

1. ONLY TRAINED PERSONNEL SHALL RIDE ON THIS MAN-RIDING CONVEYOR.
2. In the event of a conveyor stoppage, riders are to climb off the belt, and the conveyor shall not be re-started until the responsible person appointed by the Manager has satisfied himself that it is safe to do so.
3. The following requirements, as detailed in the training documentation, are to be particularly noted:
   a) Boarding and alighting is only to take place at established stations.
   b) Riders are to face the direction of travel.
   c) Riders are to sit in the centre of the belt. No clothing or articles are to protrude outside the confines of the belt.
   d) A MINIMUM distance of 5m is to be maintained between riders.
   e) Riders are to behave in an orderly manner.
   Standing or walking on the belt is only permitted when boarding or alighting.
   f) Small tools or equipment may only be carried in a suitable shoulder bag, allowing free use of both hands.
   g) Man riding may only take place if the blue light at the boarding station is lit, indicating that all safety devices are fully operational.
   h) Cap lamps and leads are to be securely fastened BEFORE boarding the conveyor belt.
4. It is the responsibility of all riders to familiarise themselves with the details of the regulations and riding procedures, and of any subsequent amendments. Copies are available at the conveyor control room.

Figure 4. Notice displayed at each man-riding station.

Once trained on surface, novices are taken to the man-riding conveyor and shown by example how to board and alight. They first ride on the top belt, and only once they are found to be proficient in boarding and alighting are they allowed to ride the bottom belt. It was found that novices experienced most difficulty in alighting from the bottom belt, and therefore special attention is paid to this area.

CONCLUSION

The man riding belt conveyor has proven to be a convenient and safe means of transportation for persons properly trained and authorised to ride it. Apart from the initial capital cost, the additional costs in terms of operation and maintenance are negligible.

There are therefore significant cost savings over the use of a dedicated personnel carrier or chair lift, and the added convenience of quick access to working areas can only contribute to productivity in a modern gold mine.

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