HIGH-LIFT BELT CONVEYORS FOR UNDERGROUND HARD ROCK HAULAGE

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ABSTRACT

The scale of underground hard rock mass mining operations is increasing. The International Caving Study [1] categorised current and future underground mass mining operations by production rate as 'large', 'bulk' and 'super', with category limits at around 10 and 25 Mt/a. 'Super' category production rates are approaching 45 Mt/a. 'Super' category lifts are approaching 2 000 metres.

Multi-flight belt conveyors are being applied to haulage systems for underground hard rock mass mining operations in configurations capable of achieving the 'super' category lift and production rates normally associated with vertical shaft hoisting systems.

This paper presents details of current belt conveyor systems in underground mass mining operations, and characterises their lift and production rate limits.

1. INTRODUCTION

The International Caving Study identified an increasing trend in the scale of underground mass mining operations. Current and future underground mass mining operations were categorised as 'large', 'bulk' and 'super'. Table 1 and Figure 1 present details of a selection of operations in each of these categories [1],[2],[3],[4],[5],[6].

The 'large' category was defined as producing 4 - 6 Mt/a; 'bulk' as producing 10 - 20 Mt/a; and 'super' as producing or planning to produce in excess of 25 Mt/a.

The 'super' mines are addressing production rates exceeding 40 Mt/a and lifts up to two thousand metres. The haulage systems for these 'super' underground mass mining projects are based on hoisting and belt conveying technologies, and in some cases incorporate multiple streams with multiple flights in each stream. The proposed Resolution Mine will incorporate three 2 000 metre lift hoisting streams in each production shaft for 40 Mt/a [3]. The proposed Chuquicamata Mine will incorporate one stream of three conveyor flights for 45 Mt/a with a total lift of 1 500 metres [4]

Class	Location	Prod'n Mt/a	Hoist Total Lift m	Conv. Total Lift m	No Streams	No Flights
Large	Koffiefontein	1.2	620		1	1
	El Salvador	2.5				
	Cullinan	3.3	500	303	2	4
	Brunswick	3.6	1 125		1	1
	Finsch	3.6	763		1	1
	Tongkuangyu	4.0		410	1	1
	North Parkes E26	5.0	505	345	1	3
	Telfer	5.0	1 113		1	1
	Ridgeway	6.4		1 058	1	4
	Mount Isa Copper	7.4	1 073		1	1
	Argyle	8.0		394	1	1
Bulk	Palabora UG	10.0	1,290		1	1
	Henderson	12.0				
	Olympic Dam	12.0	850		2	1
	Freeport DOZ	14.0				
	Andina	16.0				
	Malmberget	16.0	800	235	1	2
	Cadia East	24.0	-	1 400	1	5
Super	Kiruna	27.0	1 223		1	2
	Palabora OC	31.0	295		1	1
	Bingham Canyon	40.0	1 269		2	1
	Resolution	40.0	2 000		3	1
	El Teniente	45.0				
	Chuquicamata	45.0		1 500	1	3
	Freeport Grasberg					
	Mount Keith					

Table 1. Details of 'large', 'bulk' and 'super' mass mining operations

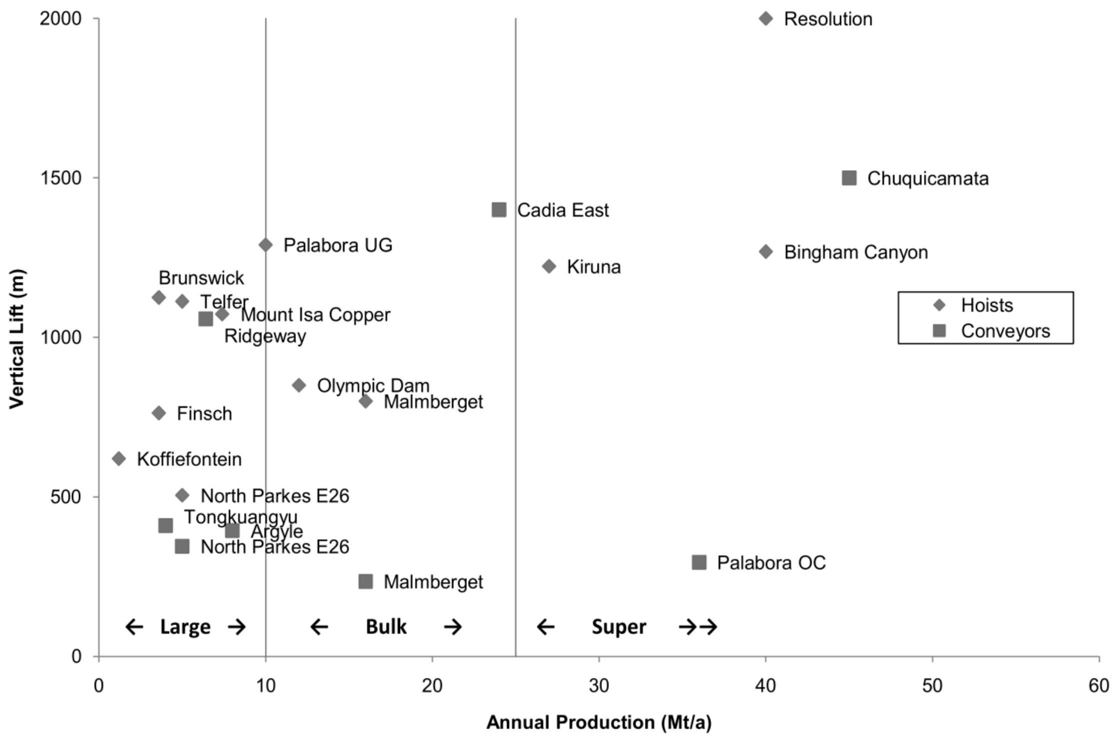

Figure 1. Vertical lift vs. annual production of 'large', 'bulk' and 'super' mass mining operations

This paper presents an overview of current belt conveyor systems in underground mass mining operations, and describes their lift and production rates. The application limits are expressed with reference to the constraints imposed by the use of drum and friction winder hoisting systems.

2. HAULAGE SYSTEMS FOR UNDERGROUND MASS MINING

2.1 Belt Conveying Systems

Details of belt conveyors currently operating or planned for future operation in underground mass mining operations are presented in Table 2. Belt conveying is a continuous process. Each conveyor in a multi-flight conveyor stream delivers to the tail of the downstream conveyor.

Belt conveying systems for hard rock mines incorporate a crushing station to reduce the run-of-mine material to a size suitable for conveying, and a tramp detection and removal system to remove tramp material from the ore stream to prevent belt damage and blockage. The tramp detection and removal system incorporates tramp magnets, metal detectors and, in some cases, facilities for manual tramp removal. This equipment is configured appropriately for the size, shape, magnetic properties and quantity of tramp anticipated.

Location	Flow Rate t/h	Lift m	Belt Speed m/s	Belt Width m	Carcass
Ridgeway	1 100	500	3.7	1.050	ST5500
Argyle	1 450	387	4.5	1.050	ST4000
Cadia East	4 050	408	5.2	1.500	ST7000
Palabora OC	5 100	295	4.1	1.800	ST6600
Chuquicamata	5 500	540	6.0	1.830	ST10000

Table 2. Details of high lift belt conveyors in underground mass mining operations

2.2 Hoisting Systems

Hoisting is a batch process. Ore hoisting systems for underground hard rock mines incorporate crushing stations, tramp detection and removal systems similar to those provided for belt conveying systems, skip loading stations, skip hoists and skip dumping stations.

A skip loading station is required to batch load the crushed run-of-mine material to the ore skips. The system typically incorporates a surge bin, a weigh hopper and interconnecting chutes and gates.

A skip dumping station receives skip loads to a surge bin and feeds this material to the next stage in the system.

A skip hoisting system incorporates a winder, a head frame, a pair of skips and interconnecting ropes. The winder and the interconnecting ropes are arranged to support the skips so that one skip balances the other - that is, one is raised as the other is lowered.

Hoisting systems are driven by either drum or friction winders. The head ropes of a drum winder are terminated to the winder drum and coil onto the drum as the associated skip is raised and off the drum as the skip is lowered. The head ropes of a friction winder pass over the drum and are driven by friction between the rope and the drum shell.

Friction winder drums are fitted with multiple head ropes. Friction winder skips are fitted with tail ropes to maintain the rope tension ratio for no slip at the drum.

Drum winders are configured with one or two head ropes on each skip. Drum winder skips have no tail ropes.

3. LIFT AND PRODUCTION RATE CHARACTERISATION

3.1 Free Length

Belt conveying and hoisting systems are limited in lift and production by the strength and weight properties of the belt or rope respectively.

The ratio of the strength of a tension element to its weight per unit length is known as its free length - that is, the maximum length that can support its own weight. The weight of the rubber that encases and protects the conveyor belt cords reduces the free length of the assembly.

The standard range of steel cord belt constructions defines the combinations of cord pitch and cord diameter that provide for greater free lengths, thus higher belt strengths.

Conveyor belting is also provided with additional cord protection rubber covers at the carry side and at the pulley side. The required cover thickness depends on the application loading conditions, loading frequency, and material lump size, density and abrasiveness.

An application that is categorised as having a light cover duty can be fitted with a belt having lighter covers than can an application assessed to have a severe cover duty. Hence, belt constructions for light duty applications have greater free lengths.

Figure 2 illustrates the impact of belt strength and cover duty on belt free length for a range of belt constructions and for two extremes of cover duty. The free length of conveyor belting ranges from around two kilometres for low strength carcasses to around eight to ten kilometres for high strength carcasses, depending on the cover duty.

The free length of winder ropes is constant across a range of rope diameters at around 17 km.

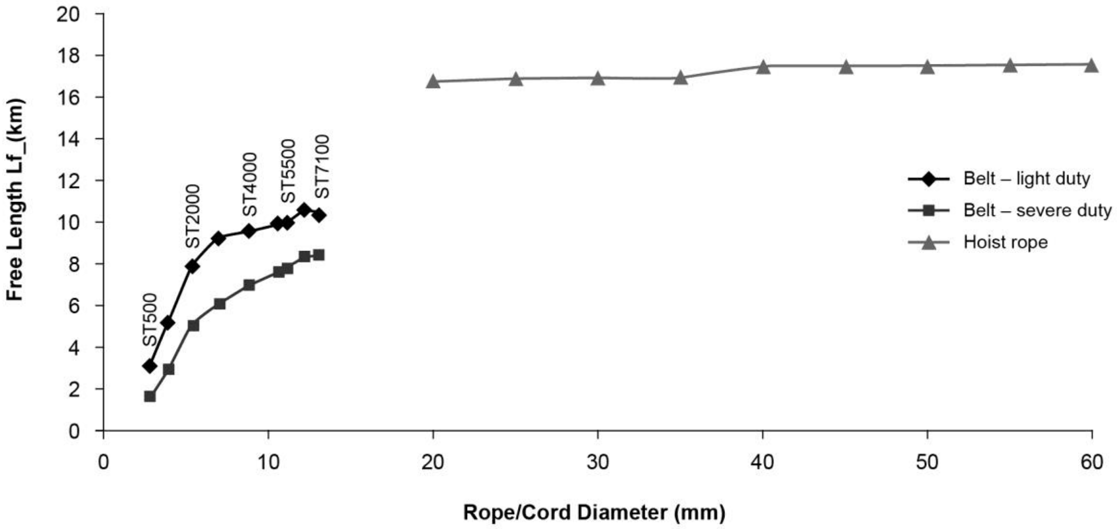

Figure 2. Free length of conveyor belting and winder ropes

3.2 Safety Factors

Belt factors of safety are selected for an application taking into account measures to ensure the integrity of the splice fabrication, the fatigue duty to which the splice is subjected, and the additional stresses generated in the belt at the head end transition [7].

Splice fabrication is assessed with regard to lack of dust, protection against sun exposure, ambient temperature, worker qualifications, quality of splice materials, and the quality of the vulcanising equipment.

The splice fatigue duty is assessed with regard to expected life, consequence of failure, operating conditions (for example, corrosion, impact damage), starting and stopping frequency, and the return frequency.

The minimum belt factor of safety for a high lift underground hard rock application is around 5.2 where:

- the splice fabrication assessment is favourable
- the splice life assessment recognises the issues associated with life expectancy, consequences of failure and the physical demands of the application
- the head end transition geometry is generous.

Rope factors of safety for hoisting systems are selected for rope life, taking into account the fatigue duty to which the rope is subjected. A rope factor of safety of 5.1 has been applied in this characterisation of lift and production rate.

3.3 Speed

Belt conveyor production is constrained by practical limits on the belt speed. These limitations are associated with noise and dust generation, and the risk of damage and injury.

Hoisting system production is also restricted by practical limits on the rope speeds that are associated with rope and shaft guide resonance effects. The hoisting system characterisations presented below are based on maximum rope speeds of 19 m/s. A typical hoisting cycle is depicted in Figure 3. The cycle time of a hoisting system increases linearly with increasing lift.

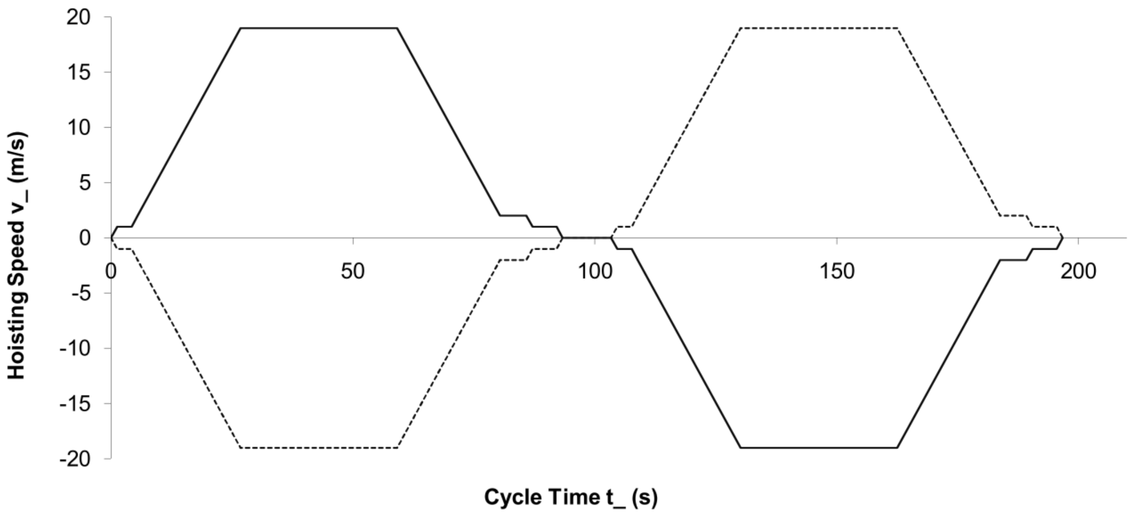

Figure 3. Hoisting cycle for characterisation and lift, and production rate

3.4 Belt Conveyors

The maximum belt tension in a high lift belt conveyor is at the high tension side of the discharge pulley and is calculated as the sum of the tail end tension and the carry side secondary, slope and main resistances.

Generally, for high lift applications, the tail end tension is determined by sag; hence:

$$T_{max} = \frac{(m'_L + m'_G).a_o.g}{8.h_{rel}} + F_{No} + (m'_L + m'_G).g.H + (m'_L + m'_G + m'_{Ro}).\frac{H}{\tan\delta}.f.g$$

The maximum allowable belt tension is the ratio of the carcass strength to the belt factor of safety selected for the application. The maximum lift for a given application is calculated as a function of the maximum allowable belt tension.

The productivity of a belt conveyor is independent of its length or lift.

Typical belt conveyor lift and production rate characteristic curves are presented in Figure 4 for belt widths increasing from 1.0 metre in steps of 0.2 metres, and belt carcasses from ST500 to ST7100.

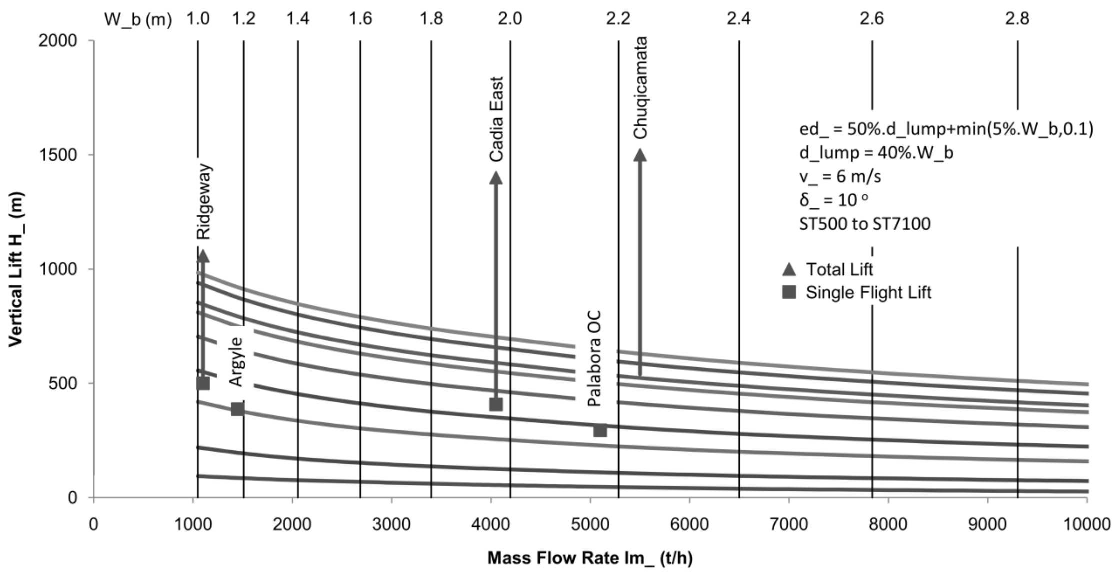

Figure 4. Lift and production rate characteristic curves for high lift belt conveyors

3.5 Hoisting Systems

The maximum rope tension in a hoisting system is calculated as the sum of the weights of the head ropes, the conveyance and payload, and the tail ropes:

$$T_{max} = (RL_s + H).N_{hr}.m'_{hr}.g + pl.(1 + r_c).g + RL_{tl}.N_{tr}.m'_{tr}.g$$

The maximum allowable rope tension is the ratio of the rope strength and the rope factor of safety selected for the application. The payload for a given application is calculated as a function of the lift and the maximum allowable rope tension.

The payload of a hoisting system reduces with increasing lift. The cycle time increases with increasing lift. The productivity of a hoisting system reduces with increasing lift due to both the reducing payload and the increasing cycle time.

Typical lift and production rate characteristic curves are presented in Figure 5 for a two-head rope drum winder and a six-head rope friction winder with head rope diameters from 20 - 60 mm.

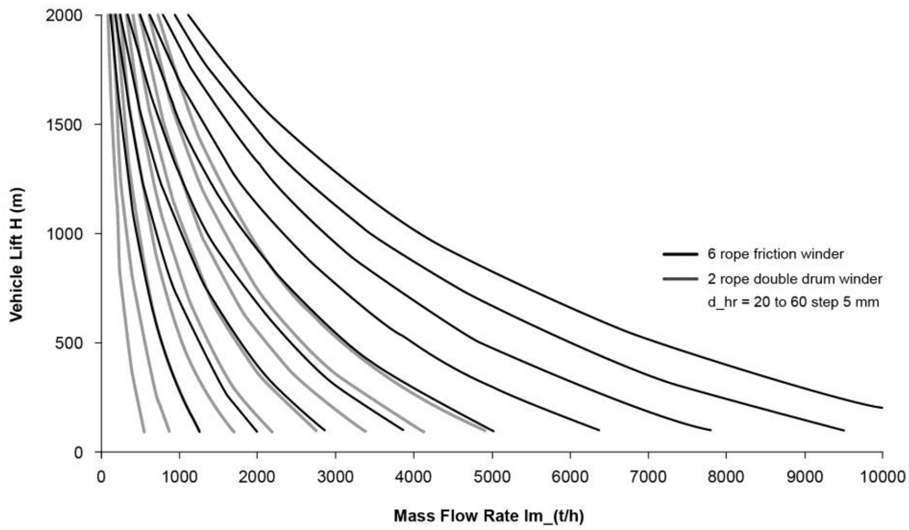

Figure 5. Lift and production rate characteristic curves for drum and friction winders

3.6 Comparison of Belt Conveyors and Hoisting Systems

Figure 6 presents the lift and production rate characteristic curves for high lift belt conveyors overlaid on those for drum and friction winders.

Drum and friction winders can operate at lifts exceeding 2 000 metres and are limited in production to around 4 000 t/h for two-rope friction winders, and around 10 000 t/h for six-rope friction winders. Hoisting systems are operated in serial and parallel combinations to deliver the production rates and lifts required for the ‘super’ mass mining operations.

Belt conveyors are limited in lift to around 800 metres by belt strength, and are further limited by belt troughing and tracking issues for combinations of narrow belt and high belt strengths. Belt conveyors are unlimited in production beyond 10.00 t/h. Relatively uncomplicated serial combinations of belt conveyors can deliver the lift requirement of a ‘super’ mass mining operation.

This is demonstrated at Ridgeway Mine where four flights have a total lift of 1 058 metres, and is further demonstrated in the plans for five flights and 1 400 metres total lift at Cadia East and three flights for 1 500 metres total lift at Chuquicamata.

The characteristic curves presented in Figure 6 illustrate that the production rate and lift requirements of a ‘super’ mass mining operation can be delivered by serial combinations of belt conveyors at conservative belt speeds and with conventional belt constructions.

A ‘Beyond Super’ duty [10] with a 2 000 metre lift at 10 000 t/h would require, allowing for lift losses at the transfers, a conveyor system with two streams of 5 000 t/h, each with four flights of 520 metre lift. The belt would be two metres wide, ST5500 running at 6 m/s.

A comparable hoisting system for this duty would require three streams of 3 333 t/h, each with two flights of 1 085 metre lift. The winder would be a six-rope friction winder. The head ropes would be 60 mm diameter hoisting 96 t payload skips.

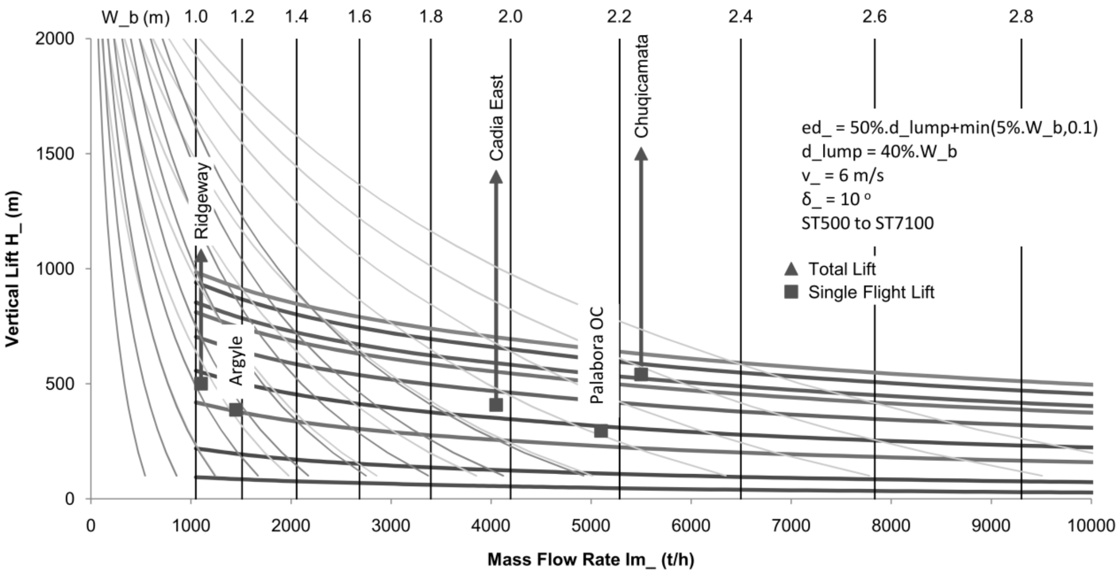

Figure 6. Lift and production rate characteristic curves for winders and high lift belt conveyors

Comparative capital cost estimates for these systems indicate a 20% disadvantage for the conveying system. Demand power estimates indicate a 30% RMS power advantage for the conveyor system. On this basis, the life-of-mine costs will favour the conveyor system. A further advantage of the conveyor system over the hoisting system is the 50% peak power requirement of the conveyor system.

Pratt’s [4] assessment of belt conveyors and hoisting systems for reliability and flexibility noted a number of advantages associated with belt conveyor hoisting systems. He noted with reference to reliability that the ‘ ... skills base required for the support of a large conveyor installation is more universal and often already available to a haulage system operator’. With reference to flexibility, he noted that the incremental cost of additional flexibility is not great, and that flexibility is available in the selection of numbers of lifts, belt widths, belt speeds, installed power and belt constructions.

4. CONCLUSION

This paper has presented an overview of current high lift belt conveyors and their application to underground hard rock haulage. Their lift and production rate characteristics have been compared with vertical shaft hoisting systems based on two-rope double-drum and six-rope friction winders.

These characterisations have been presented in the context of the increasing scale of current and future underground mass mining operations. Production rates are approaching 45 Mt/a in mines planned to operate with lifts up to 2 000 metres.

Relatively uncomplicated multi-flight belt conveyors are being applied to haulage systems for underground hard rock mass mining operations in configurations capable of application at these extremes of duty.

These multi-flight belt conveyor haulage systems can offer significant reliability, flexibility and operating cost advantages.

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NOMENCLATURE

a	idler spacing
d	diameter
F	resistance
FS	factor of safety
f	conveyor friction coefficient
g	acceleration due to gravity
H	vertical lift
Im	mass flow rate
Lf	free length
m'	mass per unit length
N	number
pl	conveyance payload
RL	relative level
rc	ratio of conveyance mass to payload
T	tension force

t	time
v	velocity
W	width
δ	slope

Postscripts

b	conveyor belt
f	serial flights
G	conveyor belt
Gk	conveyor belt cord
hr	head rope
L	conveyor burden
max	maximum
N	secondary
o	carry side
R	roller
s	parallel streams
sh	head sheave
u	return side

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John Spreadborough, BEng Mech, MIEAust, RPEQ is a mechanical engineer and technical executive with Parsons Brinckerhoff. His area of specialisation is in bulk materials handling. He has more than 25 years' experience in the mechanical design, construction and commissioning of materials handling plant and equipment for a range of bulk materials.

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