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The Evolution of Curved Conveyor Systems for the Transportation of Minerals

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THE EVOLUTION OF CURVED CONVEYOR SYSTEMS FOR THE TRANSPORTATION OF MINERALS

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1. SUMMARY

Horizontal curves often combined with vertical plane changes offer economies when designing long distance belt conveying systems.

In the past it has been necessary to include transfer stations which were not necessarily determined by the length of the conveyor system but by the lay of the land. Transfer stations not only increase capital costs, but also increase the operating and maintenance costs. Therefore, the elimination of transfer stations decreases capital and running costs thereby making the system more economical to install and operate.

This paper is presented to show the development of the long distance belt conveyor with respect to curved conveyors and, in particular, the "Cable Belt" conveying system.

2. INTRODUCTION

Ever since conveyor systems have been proved to be the only economically viable long distance transport system, so the demands placed on conveyor systems have been constantly increased. For example, in the 1950's conveyor lengths of less than 1 Km were the norm and in 1980 "Cable Belt" supplied the world's longest single flight conveyor at 30,4 Km to Worsley Alumina, Western Australia.

Initially, longer conveyor lengths were achieved by linking several short conveyors together, such as the 98,6 Km conveyor system in Morocco made up of 10 flights with lengths from 810 m to 11 649 m.

In many cases multi-flight systems were installed, not because of engineering limitations, but because of the access available along the conveyor route either topographically or from land ownership. The principal disadvantages of transfer points in a conveyor system are increases in capital and operating costs. Capital costs are increased because of the additional drive units and associated power along the conveyor line, and sophisticated drive monitoring gear. Operating costs are increased from the additional maintenance required and the reduction in component life, such as belt, as a result of short cycle times.

As a result conveyor designers and manufacturers have developed technology allowing them to curve a conveyor so minimising and frequently eliminating transfer points along the route. Initially curves in conveyors were little more than slight deviations, today curve radii can go as low as 500 m and conveyors can be installed with both left and right hand curves in the same system.

3. CURVE DESIGN CRITERIA

The radius at which a conveyor can be curved is dependent upon the tensions in the system and the ground profile at the point of curvature. Curve radii are greater in high tension areas of a conveyor, such as at the drive unit, than they are in low tension areas, such as along the conveyor line. Similarly tighter curve radii can be achieved on brows than in catenaries.

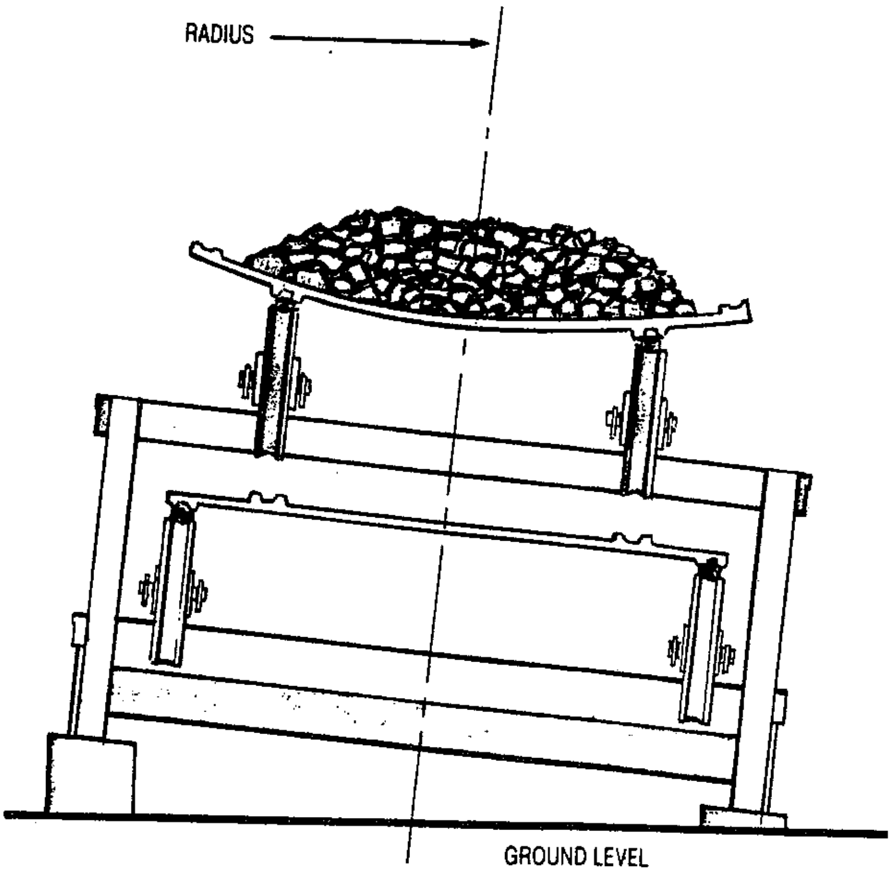
In designing a curved conveyor, it is essential that the system is designed to take account of all possible loading conditions including empty running, on and off loading and all up or down gradients loaded with the rest of the system empty. Thus the radius of a particular curve must be designed to cater for the following transient tensions on brows and through catenaries:

- Fully loaded tension on the top line including start-up acceleration factor of safety.
- Fully loaded top line under maximum tension.
- Partly loaded top line under maximum tension.
- Maximum tension on the bottom line including start-up acceleration factor of safety.
- Maximum tension on the bottom line under transient load conditions.

Unless a curved conveyor can be designed to accept all of the above loading irregularities, the operator will be required to tailor his production plans to suit the conveyor, rather than the conveyor operating to suit production plans.

On a curve the belt supports are inclined away from the centre of the curve. By inclining and close pitching linestands in this manner the induced radial loads are accommodated. The degree of inclination is determined by tensions and the material repose angle.

In some cases conventional conveyors also have to angle the support idlers, as well as tilting the linestands, to minimise belt wander. This is not the case with the "CABLE BELT" system where the drive cables are positively located on the line pulleys and the belt is positively located on the drive cables by the continuous 'V' shoe forms moulded onto the belt.



"Cable Belt" linestand in a curve

Future developments aimed at changing the relationship between the belt shoeform, cable and pulley groove are already under test. These tests have already shown that the currently acceptable minimum curve radius will probably be halved in the next few years.

4. BENEFITS OF CURVED CONVEYOR SYSTEMS

In the majority of instances a curved conveyor has been selected for the application as the optimal alternative to a multi-flight system. In the instances where a curved conveyor has replaced a trucking operation, the replacement has been associated with increases in output etc.

The principal benefits of a curved conveyor over a multi-flight conveyor system are:-

- A single drive unit, only requiring high voltage power at one point and usually located in the same area as other high voltage equipment.

- No high voltage power required along conveyor line.

- Elimination of intermediate sequencing, monitoring and surge capacity.

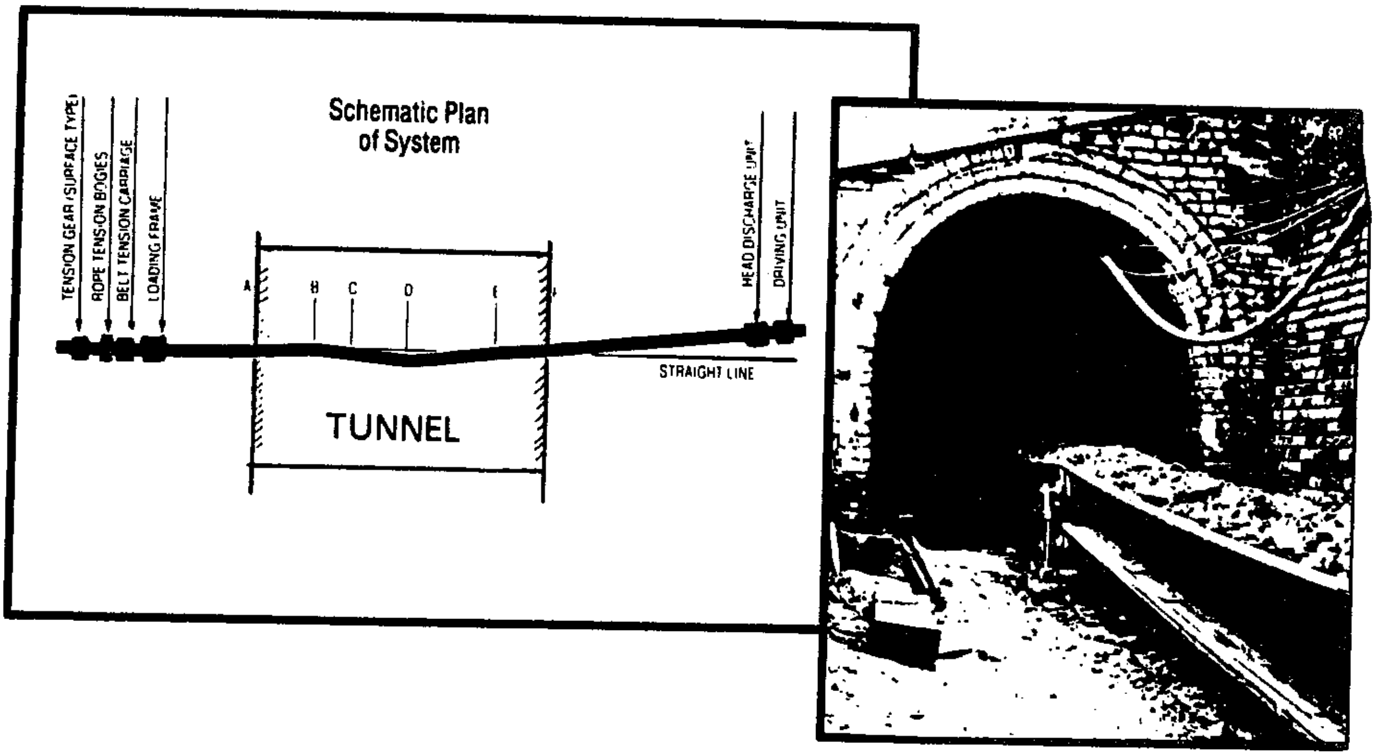
- No transfer points eliminates spillage along the conveyor line and minimises working/degradation of the material.

- Greater operational availability is achieved with a single flight than multi-flight conveyor, minimising downtime and maximising output.

The above points contribute towards a reduction in capital costs for a curved conveyor compared to a multi-flight conveyor system. In terms of operating and maintenance costs, mechanical and electrical maintenance is reduced by eliminating the intermediate drives. From the increase in the conveyor cycle time there will be a proportionate increase in belt life (and in the case of Cable Belt an increase in cable life as well).

5. CURVED CONVEYORS OVER 1 KM LONG

"Cable Belt" Ltd. installed the first known curved conveyor for the National Coal Board in England in 1955 at Thornhill Colliery. The conveyor carried coal 1 349 metres from a new pit head to nearby coke ovens. Part of the route lay through an existing tunnel which required the conveyor to be curved six times along its length.



The "CABLE BELT"conveyor at Thornhill Colliery

The oldest curved conveyor still operating was installed at the National Coal Board's North Celynen Colliery in 1965 by "Cable Belt Ltd." This 2 286 metre long conveyor has three curves along its length.

The world's longest curved conveyor system is the 11 385 m single flight "CABLE BELT" conveyor operating at the Luanshya Copper Mine, Zambia. The conveyor, which was installed in 1983, has two 4 000 metres radius curves along its length. The discharge point of this conveyor deviates by 70° from the original conveyor line.

The longest curved conventional conveyor is operated at Societe de Nickel's MEA Mine in New Caledonia. The 11 120 m conveyor has four horizontal curves along its length.

Currently under construction are three curved conveyors which, when installed, will be the world's longest curved conveyor systems. All three systems are "CABLE BELT" conveyors and are being installed in U.S.A. (19 355 m), Middle East (18 113 m) and India (14 550 Km). The conveyor with the most number of curves in operation at present is the "Cable Belt" at the National Coal Board's Horden Colliery. The 6 492 metre underground conveyor has 11 curves along its length.

From the following table it can be seen that there are 28 curved conveyors installed or being installed which are over 1 000 m long. Of this total length of 153 kilometres of curved conveyors worldwide, 57 kilometres is conventional conveyors and 96 kilometres is "CABLE BELT" conveyors.

CURVED CONVEYORS OVER 1 KM LONG

OPERATOR	COUNTRY	TYPE OF CONVEYOR	YEAR INSTALLED	LENGTH (m)	MATERIAL CONVEYED	CAPACITY (m.t.p.h)	BELT WIDTH (mm)	SPEED (m/sec)	POWER (kW)	NUMBER OF HORIZONTAL CURVES
Lower Colorado River Authority Texas	U.S.A.	Cable Belt	1987*	19355	Lignite	1633	1200	4,3	3360	2
D.S.W.	Middle East	Cable Belt	1986*	18113	Potash	800 (Top) 500 (Bottom)	950	4,6	4000	11
National Aluminium Company of India	India	Cable Belt	1985*	14550	Bauxite	1800	1050	4,5	2000	11
Zambia Consolidated Copper Mines	Zambia	Cable Belt	1983	11385	Copper Ore	850	950	3,4	1194	2
Societe Le Nickel, Mea Mine	New Caledonia	Conventional	1980	11120	Nickel Ore	560	800	0 to 3,6	821	4
Coal & Allied Operation (Pty) Ltd. Hunter Valley	Australia	Cable Belt	1982	7820	R.O.M. Coal	2000	1050	4,1	1500	2
Middelburg Mine Services, Rand Mines Ltd.	South Africa	Cable Belt	1983	7327	Coal	1400 1866	1050	3,0 4,1	1500	1

OPERATOR	COUNTRY	TYPE OF CONVEYOR	YEAR INSTALLED	LENGTH (m)	MATERIAL CONVEYED	CAPACITY (m.t.p.h)	BELT WIDTH (mm)	SPEED (m/sec)	POWER (kW)	NUMBER OF HORIZONTAL CURVES
	Indonesia	Conventional	1981	6850	Stone	1000	800	4,0	821	1
National Coal Board, Horden Colliery	England	Cable Belt	1974	6492	R.O.M. Coal	813	1150	2,5	895	11
Quintette Coal Ltd.	Canada	Conventional	1983	5547	Coal	1800	1050	6,0	2611	1
Anglo American Corporation Ltd. Blesbok Colliery	South Africa	Conventional	1982	5200	R.O.M. Coal	300	750			1
Anglo American Corporation Ltd. Klein Kopje Colliery	South Africa	Conventional	1978	4935	Coal	1500	1050	4,6		1
Anglo American Corporation Ltd. Tutuka Power Stn.	South Africa	Conventional	1985	3750x2	Crushed Coal	1250				1
South African Iron & Steel, Durban Navigat-ion Collieries	South Africa	Cable Belt	1959	3048	R.O.M. Coal	508	1150	1,7	135	3

OPERATOR	COUNTRY	TYPE OF CONVEYOR	YEAR INSTALLED	LENGTH (m)	MATERIAL CONVEYED	CAPACITY (m.t.p.h)	BELT WIDTH (mm)	SPEED (m/sec)	POWER (kW)	NUMBER OF HORIZONTAL CURVES
	France	Conventional	1977	2740	Iron Ore	1200	1000	3,0	403	1
	Australia	Conventional	1977	2550	Bauxite				597	1
	Switzerland	Conventional	1984	2490	Stone	500	800	3,0	112	9
	Algeria	Conventional	1970	2385	Iron Ore	1000	1000	2,5	298	2
National Coal Board, North Celynen Colliery	Wales	Cable Belt	1965	2286	R.O.M. Coal	406	950	1,7	223	3
	Switzerland	Conventional	1984	2200	Stone	500	800	3,0	112	9
Compania General de Asfaltos y Portland	Spain	Cable Belt	1966	1859	Limestone	406	650	3,0	59	4
National Coal Board Yniscedwyn Colliery	Wales	Cable Belt	1961	1450	R.O.M. Coal	355	950	1,5	74	2
	France	Conventional	1979	1350	Mineral	300	650	1,7	75	1
National Coal Board Thornhill Colliery	England	Cable Belt	1955	1349	R.O.M. Coal	162	800	1,0	37	6

OPERATOR	COUNTRY	TYPE OF CONVEYOR	YEAR INSTALLED	LENGTH (m)	MATERIAL CONVEYED	CAPACITY (m.t.p.h)	BELT WIDTH (mm)	SPEED (m/sec)	POWER (kW)	NUMBER OF HORIZONTAL CURVES
Kali-Salz, Wintershall	West Germany	Conventional	1976	1232	Residue/ Waste	800	1000	3,3	530	1
Revere Jamaica Alumina Ltd	Jamaica	Cable Belt	1970	1109	Bauxite	304	800	3,2	30	4
	France	Conventional	1972	1050	Coal	1200	1000	5,3	254	1

* Under construction

CURVED CONVEYOR INSTALLATIONS

5.1 The CABLE BELT conveyor at Luanshya Copper Division, Z.C.C.M. Zambia

The Baluba orebody was discovered in 1928, but a decision to develop it was not made until the late 1960's. Earlier development was not considered attractive compared to the large (250 million tonnes) and rich Roan Antelope deposit nearby.

Assessment of the Baluba deposit confirmed the presence of cobalt as well as copper and Stage I production from the deposit commenced in 1973. At this stage of production the existing railway system coped with the daily 4 000 tonnes output. Stage II development commenced in 1975, at which time it was proved that the railway would not be able to cope with the proposed increase in output. In late 1980, the Central Engineering Division of Roan Consolidated Mine evaluated the following alternative transport systems for Stage II production.

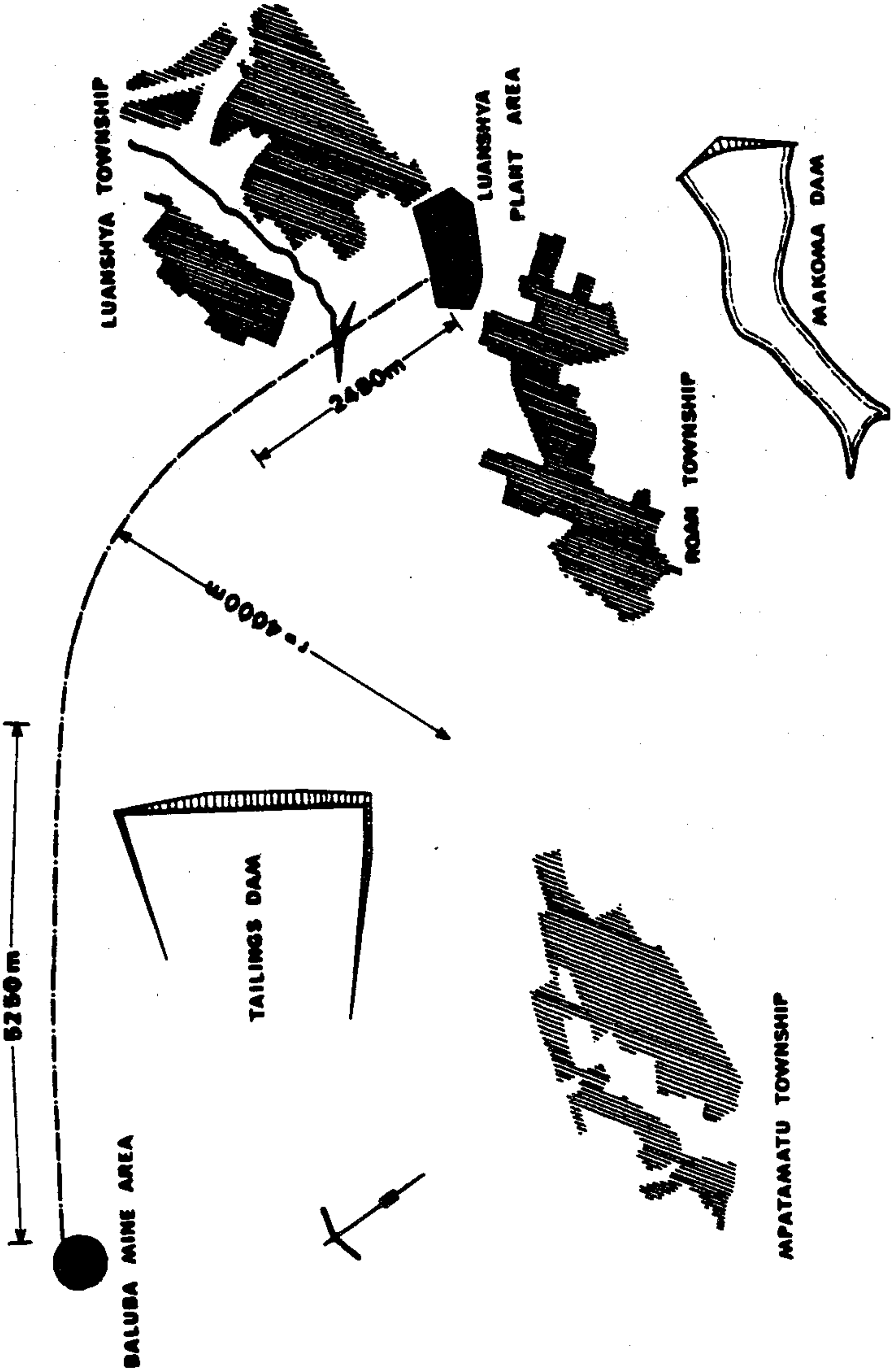
1. Off Highway Dump Trucks - rejected because of the high capital/operating and maintenance costs of running trucks over the required haul distance and tonnage over the life span of the mine.

2. Aerial ropeway - rejected as being unsuitable because of the distance and tonnage.

3. Railway system - rejected because of its reliance on imported spares, the high maintenance costs and the reliance on imported fuel in the case of diesel locomotives.

TECHNICAL CHARACTERISTICS

Conveyor Length	11 385 m
Difference in level between terminals	-34 m
Rated Capacity	850 mtph
Material	R.O.M. Copper Ore
Density	1 840 Kg/m³
Lump Size	250 x 250 x 500 mm
Daily Operating Time	16 hours
Annual Operating Time	5 824 hours
Annual Tonnage	4 950 400 mt
Belt Width	950 mm
Belt Compound	GP Rubber
Conveyor Speed	3,40 mps
Conveyor Inspection Speed	1,02 mps
Cable Size	41 mm
Cable Specification	6 x 19 (9x9x1) Fibre Core
Factor of Safety of Cable at Rated Capacity	4,16:1
Drive Motor Rating	1 194 kW
Drive Unit Rating	Continuous
Linestand Pitch	7,0 m
Return Line Pulley Pitch	14,0 m
Line Pulley Material	Polyurethane
Curve radii	4 000 m and 4 000 m
Conveyor Configuration	Head End Drive and Tension


LUANSHYA TOWNSHIP
LUANSHYA PLANT AREA
MAKOMA DAM
ROAN TOWNSHIP
2480m
r=4000m
5250m
TAILINGS DAM
BALUBA MINE AREA
MPATAMATU TOWNSHIP

5.2 The "CABLE BELT" Conveyor for Coal & Allied Operations Pty. Ltd. Hunter Valley No.1 Mine, Australia

The Hunter Valley No.1 mine had been operating for a number of years using CAT 776 articulated bottom dump haulers for the transport of between 1 and 2 million tonnes per annum of run of mine coal. These haulers operated over a private road of approximately 9 Km in length to discharge at a rail loading facility at Liddell mine. Coal & Allied Operations Pty. Ltd., who own the mine, required to increase mine output to approximately 5 million tonnes per annum and include washing facilities for most of the product. The increased capacity could not be economically handled by the trucking operation and, as part of new works worth approximately Aust. $150 million, Coal & Allied sought tenders for the design and supply of a conveying system to replace the trucks. The tenders called for an overland conveyor approximately 8 Km in length, to transport 2 000 tonnes per hour of coal from the mine stockpile/washing plant to rail loading/stockpile facilities, together with a receival bin and transfer conveyor.

Tenders were called in early 1980 for the design, supply and installation of the transportation system, seven tenderers being invited to bid. The right of way was not straight and Coal & Allied considered curved and multiflight options for this system. Site visits to "Cable Belt" installations and the conventional curved system in New Caledonia were made by Coal & Allied personnel. In mid 1980, after a detailed assessment of capital and operating costs had been made, a contract was awarded to "Cable Belt" (Australia) Pty. Ltd. The contact called for the turnkey construction of a single flight curved "CABLE BELT" conveyor within a 12 month contract period.

Coal & Allied have had over 50 operational years experience with "CABLE BELT" conveyors and with conventional belt systems.

The right of way for the conveyor route consists of approximately 5 Km of existing straight haul road with the remaining distance crossing virgin land to a terminal point not aligned with the haul road. The main feature of the curves on this system is that they occur on a high tension conveyor designed to operate under any type of loading conditions.

The conveyor does not required the curved sections to be specially loaded during transient conditions.

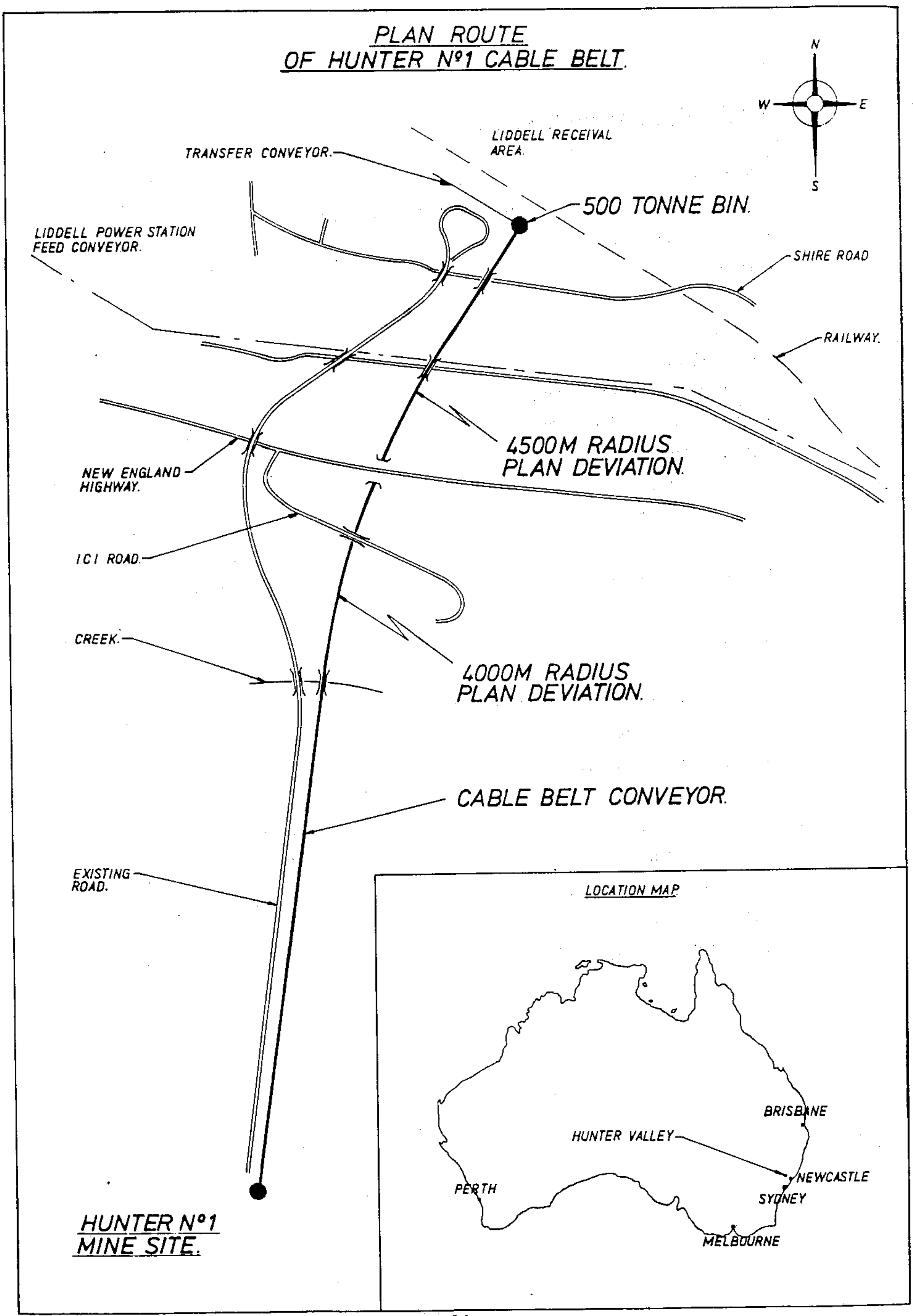
The positive tracking feature of the "Cable Belt" system ensures that the curves can be negotiated without problem, even though the transient cable tensions were in the region of 60 000 Kg. To negotiate a curve, the Cable Belt system uses standard linestand assemblies with side plates adjusted to achieve a small tilt of the cross tubes away from the centre of curvature. Apart from reducing linestand pitch to further distribute polypulley loading, no other measures are taken to construct a "Cable Belt" curve.

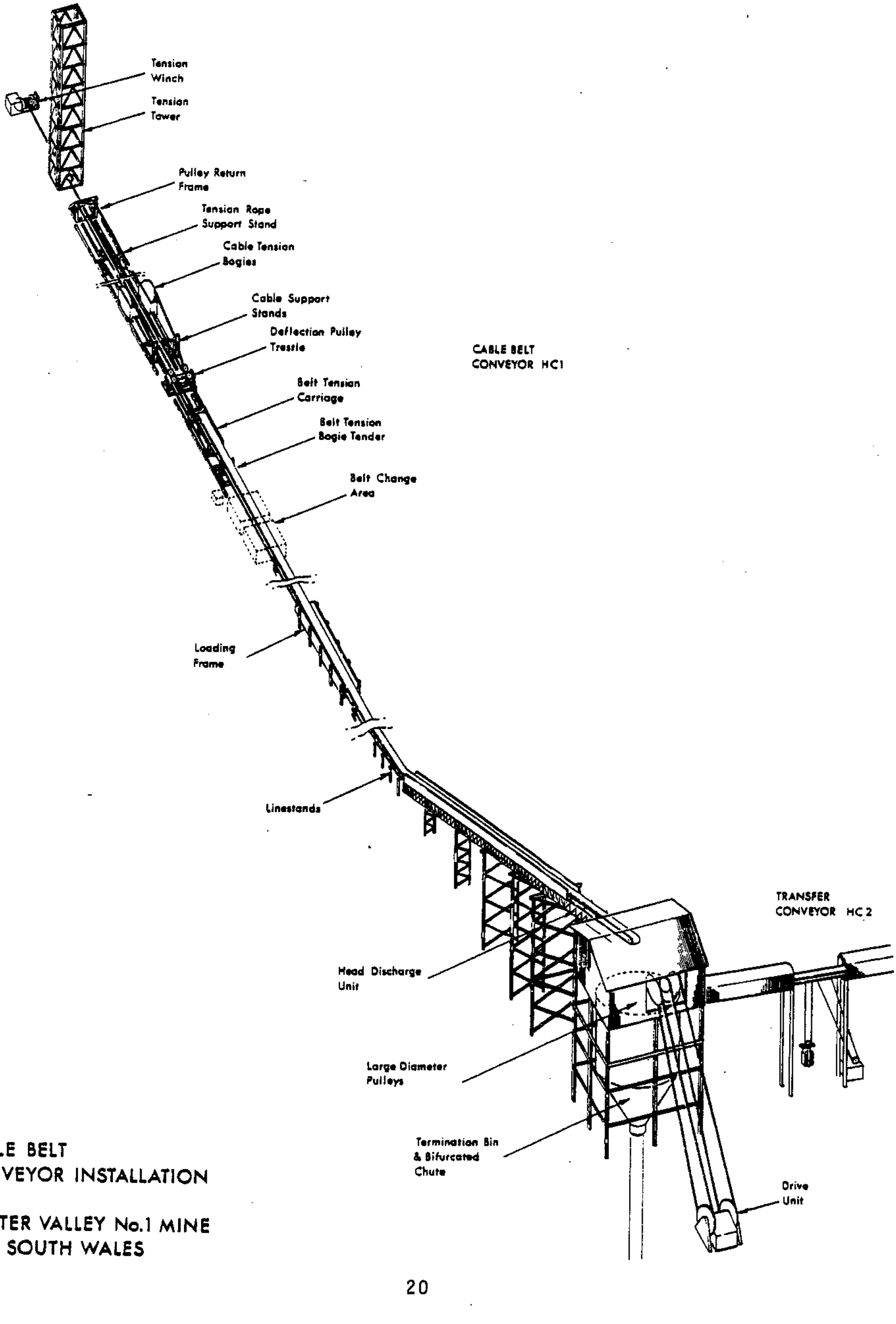
When specifying the conveyor, Coal & Allied stipulated that the belt must be 100% full at rated capacity. This was to safeguard against the common practice of overloading a belt.

To date the conveyor has run approximately 13 700 hours and has conveyed approximately 20,5 million tonnes.

TECHNICAL CHARACTERISTICS

Length	7 820 m
Difference in level between terminals	+3 m
Rated Capacity	2 000 mtph
Material	Washed and raw steaming coal
Density	800 and 880 Kg/m³
Lump Size	-30 mm
Daily Operating Time	20 hours
Annual Operating Time	4 560 hours
Annual Tonnage	7 239 300 tonnes
Belt width	1 050 mm
Belt Compound	Fire resistant, anti static
Conveyor Speed	4,10 m/sec
Cable Size	41 mm dia.
Cable Specification	6 x 19 (9x9x1) Fibre Core
Factor of Safety of Cable at Rated Capacity	3, 10 : 1
Drive Motor Rating	750 kW x 2 off
Drive Unit Rating	Continuous
Linestand pitch	4,0 m
Return Line pulley pitch	16,0 m
Line Pulley Material	Polyurethane
Curve radii	4 000 m and 4 500 m
Conveyor configuration	Head end drive, tail end tension


PLAN ROUTE
OF HUNTER Nº1 CABLE BELT.
N
W
E
S
LIDDELL RECEIVAL AREA.
TRANSFER CONVEYOR.
500 TONNE BIN.
LIDDELL POWER STATION FEED CONVEYOR.
SHIRE ROAD
RAILWAY.
4500M RADIUS PLAN DEVIATION.
NEW ENGLAND HIGHWAY.
ICI ROAD.
CREEK.
4000M RADIUS PLAN DEVIATION.
CABLE BELT CONVEYOR.
EXISTING ROAD.
HUNTER Nº1 MINE SITE.
LOCATION MAP
BRISBANE
HUNTER VALLEY
NEWCASTLE
PERTH
SYDNEY
MELBOURNE



CABLE BELT
CONVEYOR INSTALLATION
at
HUNTER VALLEY No.1 MINE
NEW SOUTH WALES

5.3 The "CABLE BELT" Conveyor System installed at Middelburg Mine, Rand Mines Ltd., R.S.A.

The initial overland conveyor enquiry from Rand Mines Ltd. called for a 3 flight (straight) conveyor system, the lengths of the flights being 1 210 metres, 2 420 metres and 3 697 metres. "Cable Belt Conveyors (Pty.) Ltd." proposed a conveyor system incorporating one curve plus an angle station, thereby deleting 2 drive stations and 1 transfer station. This proposal was accepted by Rand Mines, an order was placed on "Cable Belt Conveyors (Pty.) Ltd." in March, 1982 and the mine was brought into production in June 1983.

The "CABLE BELT" conveyor receives clean coal from the stockpile via 4 vibrating feeders, located close to the plant. From the loading points the conveyor steadily rises and negotiates a 3 460 metre horizontal radius curve before descending to the angle station, a distance of approximately 3 600 m from the loading point. At the angle station the conveyor is turned through an angle of approximately 80° and then continues in a straight line over undulating terrain to the discharge point at the rail outload station, the length from the angle station to the final discharge point is approximately 3 700 m.

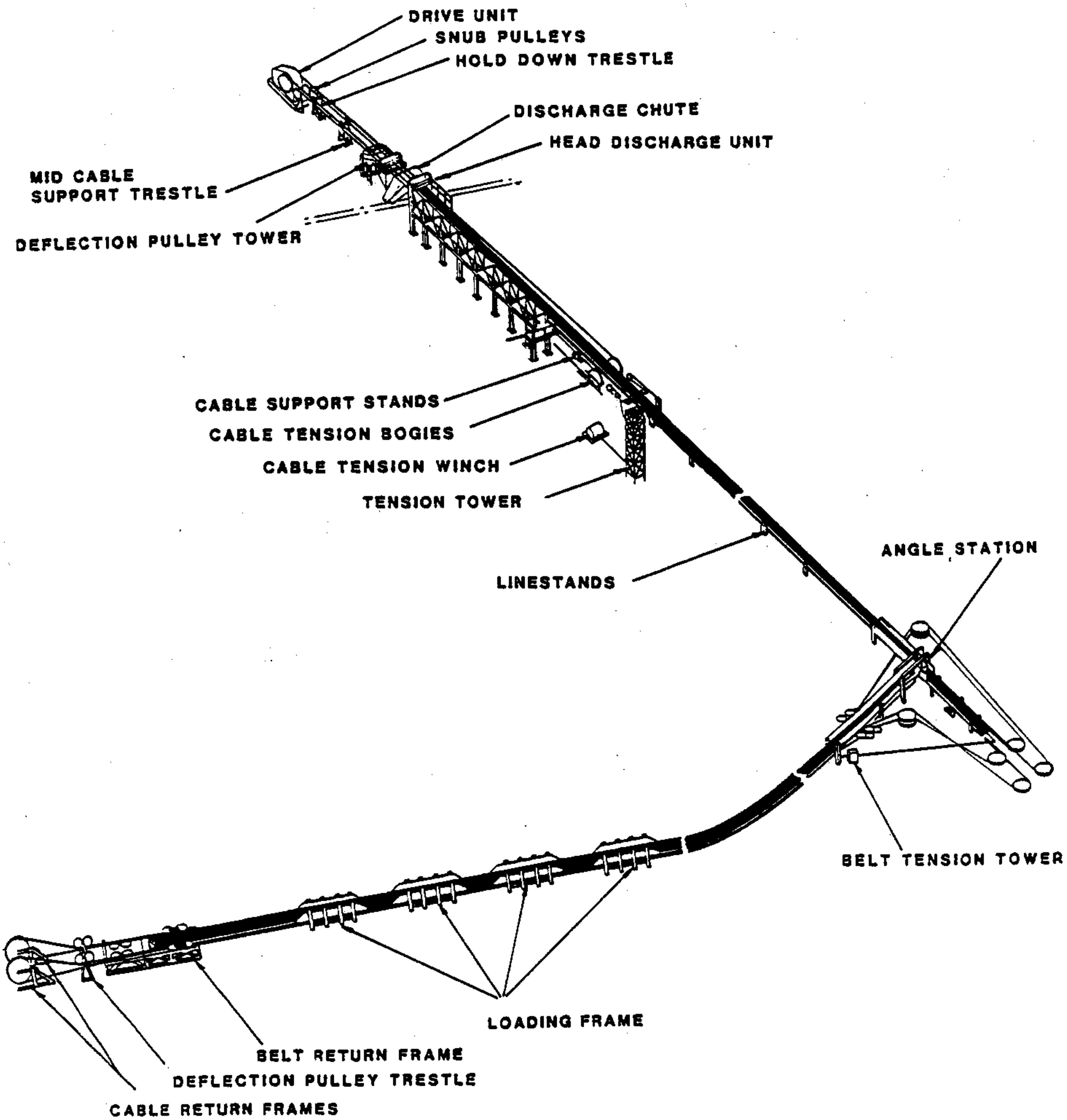
This 7 300 m "CABLE BELT" conveyor system is driven by a single drive unit located at the discharge point, in the rapid loadout area.

To date the conveyor has run approximately 7 300 hours and has conveyed approximately 6,6 million tonnes.

TECHNICAL CHARACTERISTICS

Conveyor length	7 327 metres
Difference in level between terminals	+58 metres
Rated Capacity	1 400 mtph
Material	Crushed Coal
Density	850 Kg/m³
Lump Size	-50 mm
Daily Operating Time	24 hours
Annual Operating Time	7 368 hours
Annual Tonnage	4 250 000 mt average
Belt width	1 050 mm
Belt Compound	G.P. Rubber
Conveyor Speed	3,0 mps
Conveyor Inspection Speed	1,0 mps
Cable Size	41 mm
Cable Specification	6x25(12x6+6F/1) Fibre Core
Factor of Safety of Cable at Rated Capacity	3,49:1
Drive Motor Rating	750 kW x 2 off
Drive Unit Rating	Continuous
Linestand Pitch	4,5 m
Return Line Pulley Pitch	13,5 m
Line Pulley Material	Polyurethane
Curve Radius	3 460 m
Conveyor Configuration	Head End Drive and Tension

CABLE BELT ®



CABLE BELT CONVEYOR INSTALLATION AT THE MIDDELBURG MINE, NEAR MIDDELBURG TRANSVAAL, SOUTH AFRICA

6. CONCLUSION

The development of curved conveyor systems has allowed conveyors to become even more flexible as transport systems. By curving a conveyor it is possible to optimise on a conveyor route and minimise on capital costs. The elimination of intermediate drive stations/transfer points minimises on operating and maintenance costs.

The number of conveyor contracts awarded where the route has required the inclusion of one or more curves is proof that conveyors are the most flexible and cost effective transport system for mining operations.