POWER BELT TECHNOLOGY

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1. INTRODUCTION

There is always a need for more cost-effective belt conveyor systems for the transportation of bulk products from the source to process plants or ports.

State of the art conveyor systems are based on increased operating velocities with reduced belt width. The supporting system i.e. chutes, idler rolls, pulleys, belt cleaners, transfer chutes, etc. requires a design initiative to be compatible with these high operational velocities.

It is the objective of this paper to present a new technology to meet the needs of long distance high speed conveyor belt systems with the focus on life cycle cost optimisation.

We term this new technology for the design of this belt conveyor system of the future the **Power Belt Technology.**

2. SCOPE

This paper presents the basic principles and the experimental and production plant that is installed to prove the Power Belt technology.

3. DISCUSSION

3.1 General

Some of the challenges in the optimisation of the design of belt conveying systems includes the reduction of costs associated with the installation and replacement of the belt, an increased operating life of the belt and improved system reliability.

The conventional practices of conveyor system design were challenged with respect to the above during a recent study into long distance transportation of coal. An alternative design concept was developed and evaluated in theory. The potential benefits of the concept developed are attractive for use in future new installations and in conversions of present systems.

The key questions that need to be answered are as follows:
- What considerations are applicable to the design of a Power Belt system, in terms of the design standards for conventional systems and in terms of the general specifications (e.g. Rubber specifications)?
- What factors are to be considered in the design of a Power Belt system to ensure operability and maintainability of the system?
- How are the safety of people and the protection of plant ensured for the safe operation of the system?
- What are the benefits of the Power Belt system relative to a conventional conveyor belt system?
- What future benefits are possible from the development of this technology?

3.2 Conventional conveyor belt design

Conventional conveyor belt design utilises a single belt to contain material in bulk and to provide the required tension strength to move (transport) the material. This result in a high class of belt at high cost to provide the required strength being subjected to the strenuous working conditions associated with loading and cleaning of the belt.

Further, the design of the belt carcass is such that the tension forces is distributed over the full width of the belt. Any tension influence, which impact non-symmetric over the belt width, will effect the alignment of the belt. Belt alignment is one of the main factors, which contribute to system reliability.

3.3 Power Belt

Figure 1 illustrates the Power Belt concept. A conventional conveyor is supported over its length by the Power Belt for the approximate width of the centre idler roll in a 3 roll idler configuration. The return strand, the narrower Power Belt rides on top of the conventional belt.

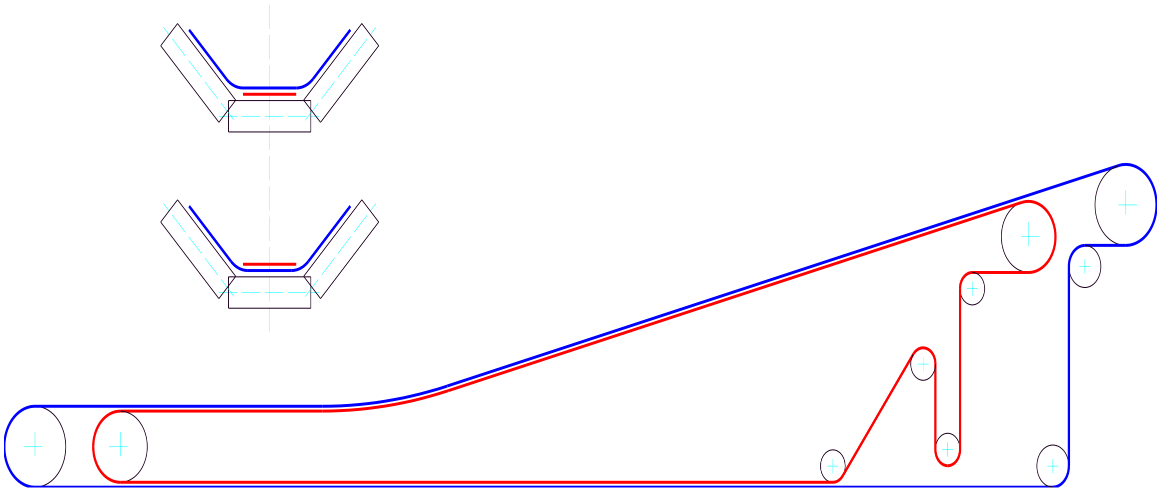

Figure 1: Power Belt Concept

In a conventional conveyor belt the function of the belt is twofold:

- Firstly the belt transports the material and supports the vertical load on the belt.
- The belt is subjected to a horizontal or axial tensile force equal to the sum of the resistant forces of the system as well as the pretension force.

The belt strength selection is based on the steady state tensile force multiplied by a factor of safety for the belt.

The Power Belt is a narrow belt positioned underneath a conventional carry belt to drive that belt. With the application of the Power Belt, the 2 functions as stated above are divided over the conventional carrying belt and the Power Belt.

The function of the Power Belt is to carry the tensile load and transmit the drive power from the drive pulley to the carry belt.

The function of the conventional carry belt is to support the bulk solid on the belt.

The main difference between a conventional conveyor belt and a Power Belt conveyor is as follows:

- Conventional System
  Drive power is transmitted to the belt by means of a limited number of drive pulleys.

- Power Belt
  Drive power is transmitted from the Power Belt to the carry belt along the length of the conveyor.

For a long conveyor system based on the conventional drive arrangement, the required strength of the belt is high due to the resultant of the resistant forces. The belt strength can be reduced by application of intermediate drive arrangements. For a long conveyor system based on the Power Belt technology, the belt strength for the carry belt is low.

Three factors determine the strength of the carry belt:

- Bending stiffness, is required to limit belt sag and unfolding of the trough.
- Tensile force, in sections where the belt is not directly driven by the Power Belt (areas such as the tripper, head end and tail end). The belt has to carry an axial load equal to the sum of the motion resistances in that section.
- Pre-tension of the belt, this is required to track the belt in case of the carry belt.

Three factors determine the strength of the Power Belt:

- By the number of drive stations.
- The motion resistances of the complete belt system.
- Pre-tension, to prevent slip at drives pulleys.

In general, application of the Power belt will result in significant reduction in the capital cost of the total system. This cost saving will increase with increasing conveyor length and increase in the number of drives for the Power Belt.

4 DESCRIPTION OF POWER BELT CONVEYOR PROTOTYPE

4.1 Conveyor Profile

Figure 2 illustrates the general conveyor profile. The conveyor length between pulleys is 644m and the overall elevation change is -16m from the tail end to the head end. The conveyors profile includes 7 vertical curves, 2 convex curves, 5 concave curves and 1 horizontal curve of 1050m. The conveyor is designed with a variable speed drive to meet production requirements ranging from 0 to 2000 tons/hour over an operational speed range between 0 to 5m/s. It is also possible to run the conveyor under reduced load conditions to a maximum speed of 12m/s for experimental purposes.

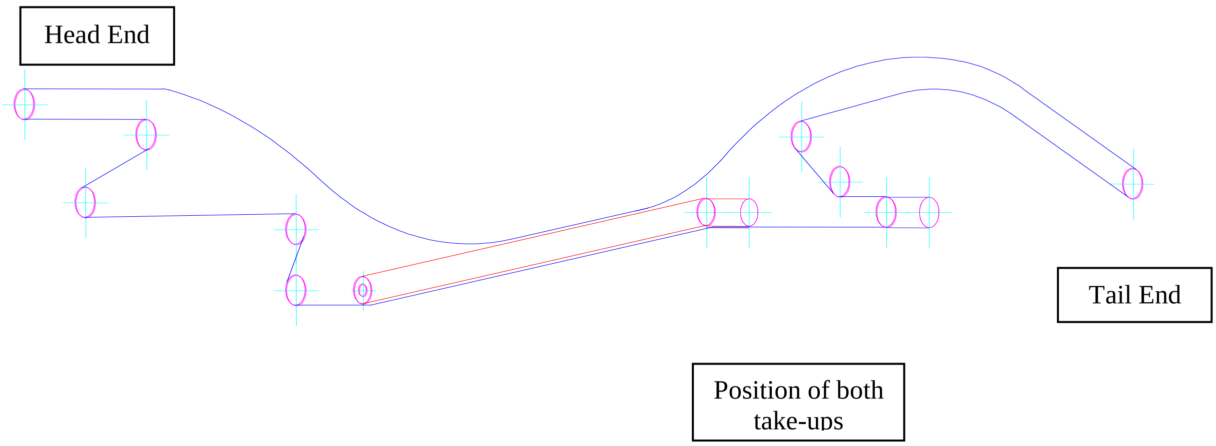

Figure 2: Conveyor Profile (Not to scale)

4.2 Head and Tail Ends of Conveyor System (Refer to Figures 6&7 in Annex 1)

This section describes the head and tail ends of the conveyor and in particular the separation and re-engagement of the carry and Power Belts. Figure 7 illustrates the tail end of the conveyor.

The carry belt has a conventional tail section and follows the normal conveyor profile. The carry belt is separated from the Power Belt just prior to the convex curve at the tail end of the conveyor. The return strand of the carry belt follows the normal conveyor profile as well, until it meets with the pulleys for the gravity take up system of the carry belt, thereafter it is re-engaged with the Power Belt at the tail pulley of the Power Belt. The tail pulley of the power belt is also the take-up pulley for pre-tensioning of the belt.

At the head end of the conveyor as illustrated in figure 6, the carry strand is being elevated to the transfer station. This profile includes both a concave and convex vertical curve. The power belt and carry belt are separated prior to the concave curve. The carry belt after separation follows the normal profile of the conveyor, the power belt in turn continues straight and bends around the head end drive pulley. The carry belt returns from the moving type head transfer pulley on the return strand and is re-engaged with the power belt at the head end of the power belt.

4.3 Horizontal Curve

The prototype conveyor incorporates a horizontal curve with a radius of 1050 m. This relatively tight radius is only possible because of the low belt tensions applicable to the Power Belt technology.

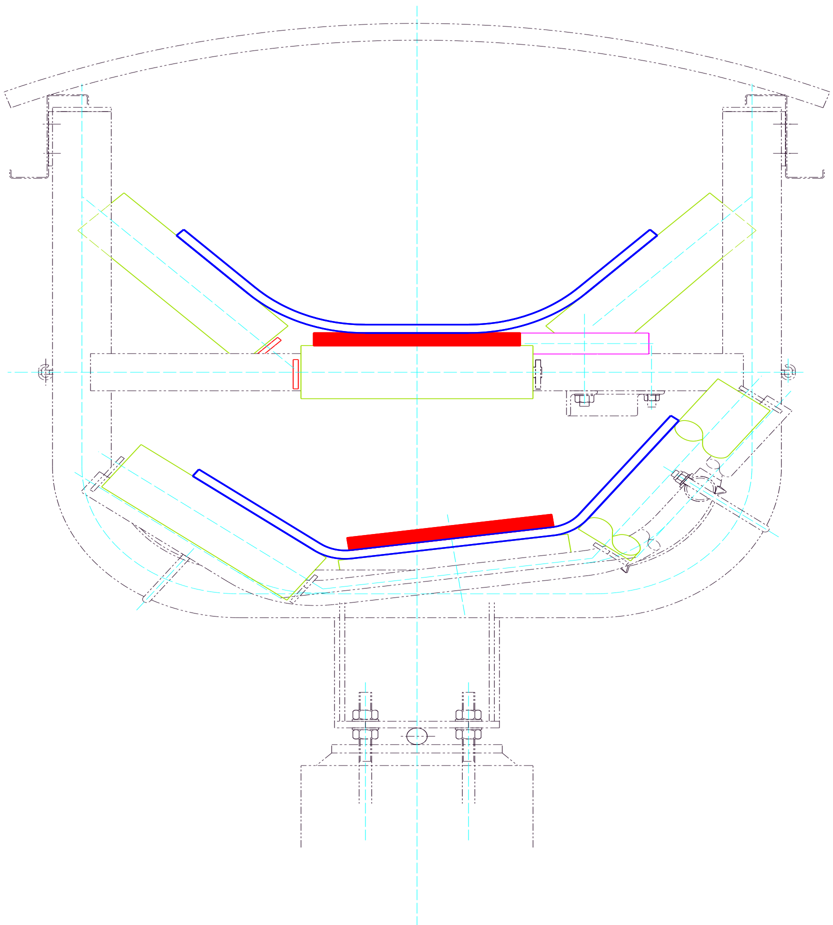

Figure 3: Module indicating carry and return side idler arrangements

On the carry strand of the conveyor in the horizontal curve section, every second idler set incorporates a flat side idler roll to restrict the movement of the Power Belt in the plane of the horizontal curve. The location of these side-guide rolls alternates from the left-hand side to the right-hand side of the Power Belt. The idler sets do not require tilt adjustment in the vertical plane, belt drift is within the movement range as provided by the idler roll width. The guide rolls are chosen so that the Power belt is centered on the middle roll.

In straight sections of the conveyor there is only an axial component of the belt tension and the idler set is only located horizontally by means of the flat centre roll.

On the return side of the belt in the horizontally curved section, there is a vertical curve – inwards component of the belts tensions that drives the belts curve inwards. To counteract this force and prevent run-off of the belt from the idlers, the idler sets are banked at an 8 degree tilt angle as shown in the above figure 3.

5 DESIGN METHODOLOGY

The power belt conveyor technology incorporates a two-belt system each with separate functionalities namely:

- The Power Belt is subjected to the tensile load and must transmit the drive power from the drive pulley to the carry belt.
- The function of the carry belt is to support the bulk solid during transportation.

5.1 Power Belt

The selection of the power belt is based on width, thickness and strength. The width of the power belt is related to the width of the carry belt and the 3-roll troughing idler center roll width. For this specific prototype installation, the carry belt width is 1050 mm. This carry belt width results in a standard middle idler roll width of 450 mm for the nominated 3-roll idler set at a 45° trough angle. The width of the power belt was selected at 400 mm, this gives 25 mm clearance at each side of the belt on the middle idler roll. The clearance of 25 mm is sufficient since guide rolls will restrict the side movement (drift) of the power belt for varying belt tension over the operational cycles.

The thickness of the Power Belt is based on the required stiffness and by the fact that the side movement of the belt has to be restricted by the narrow guide rolls that runs on the side wall of the belt. The thickness of the Power Belt in the prototype application is 30 mm. It is sensible to select a belt bottom cover at minimum thickness (4 mm); this reduces the friction at the contact face onto the idlers. The top cover thickness at 22 mm is much greater than the bottom cover. The reason for this is the expected improved dynamic behavior of the belt in the curves.

The strength or rating of the Power Belt is determined by the number of drive stations, the total resistance of the system between drive locations and the pre-tension required to prevent belt slip at the drive and to limit belt sag. The prototype installation's installed motor power is 160 kW at a single location and the pre-tension is 40 kN, the required belt strength for the power belt is 1000 kN/m. This rating of the belt is sufficient and yields acceptable safety factors.

As stated previously, the power belt bears the total system resistance in terms of the tensile load, it also supports the mass of the carry belt and material directly above the width of the Power Belt on the carry strand of the conveyor. On the return side, the carry belt supports the mass of the Power Belt, since it runs on top of the carry belt.

Calculations dictate the need to balance the combined belt tension motivational force in the direction of the horizontal curve radius (curve-inwards component), as imposed by both belts in the horizontal curve section. This is achieved by means of tilting of the return strand 3-roll idler sets at a pre-determined banking angle. The banking angle is chosen so that the overall belt drift falls within the combined width available across the idler roll's faces.

5.2 Carry belt

Similar to the Power Belt, the carry belt selection is also based on width, thickness and strength.

The prototype installation is equipped with a variable speed drive. The maximum throughput capacity of the system is 2000 tons/hour, with a normal operating capacity of 1200 tons/hour. With the belt width at 1050 mm and a 3-roll 45° troughing idler arrangement, the required operational belt speed varies between 3 m/s and 5 m/s.

Three factors determine the required strength of the carry belt i.e.:

- Bending stiffness, to reduce belt sag and to prevent the belt from unfolding in the trough.
- Tensile force in the belt, in sections where the carry belt separates from the power belt, such as at the head and tail ends. The belt is subjected to an axial load equal to the system resistances in those sections. In addition to this the belt is also subjected to the tensile load caused by a combination of the belt mass, material mass as well as the idler rolling resistances for the two wing idler rolls outside the width of the Power Belt. This tensile load is in turn transferred onto the Power Belt.
- Belt pre-tensioning requirement to limit belt sag and to ensure belt tracking.

The belt take-up tension based on the above mentioned criteria is 18 kN and the required belt strength is 250 kN/m. Standard belt cover thickness of 6 mm and 4 mm for the top and bottom covers were selected.

5.3 Belt drive frictional review

A certain amount of friction is required between the Power Belt and the carry belt to enable the drive power to be transmitted from the Power Belt onto the carry belt. This is similar to a conventional drive where a certain amount of tension is required between the drive pulley and the belt to prevent slip between the belt and pulley.

For static operation and a fully loaded belt the required friction factor is 0.035 and 0.082 respectively for the carry and return strands to prevent belt slip. For a fully loaded start –up condition, the required factors increase to 0.062 and 0.15. The corresponding friction factors for empty running steady state conditions are 0.12 and 0.074 for the carry and return strands. Empty starting requires friction factors of 0.17 and 0.11 to prevent slip between the two belts. It should be noted that the Power Belt runs underneath the carry belt on the carry strand, whereas in the return strand the carry belt is located under the Power Belt.

The minimum friction factor between two wet 60 Shore A rubber belts is 0.20. Belt slip due to insufficient friction between the Power Belt and the carry belt is therefore not to be expected.

5.4 Power Belt and Carry Belt tension Profile

Refer to Annex 2 for a detailed tension distribution around the conveyor system for the following three states viz.: starting, steady state running and stopping tensions for a load condition of 2000tph.

5.5 Transfer chutes

The design of the transfer chutes at both the head and tail ends are based on modern design concepts. Important aspects of the chute design that were considered were the relevant bulk solid flow properties. In particular, the interaction between the bulk solid and chute lining surfaces were thoroughly examined to achieve streamlined flow without blockages and spillages and for wear to be minimised.

The chute at the tail end is an open chute with a narrowing channel in the direction of flow that provides a profiled guided path for the transported material onto the receiving conveyor. The head end is a combination of both a top profile plate and a bottomed radiused section. The material is guided and consolidated in the top section ensuring that the momentum is maintained and then transferred onto the bottom chute where the momentum is maintained and discharged onto the receiving conveyor. Figure 4 and 5 below shows the arrangement at the tail and head ends respectively.

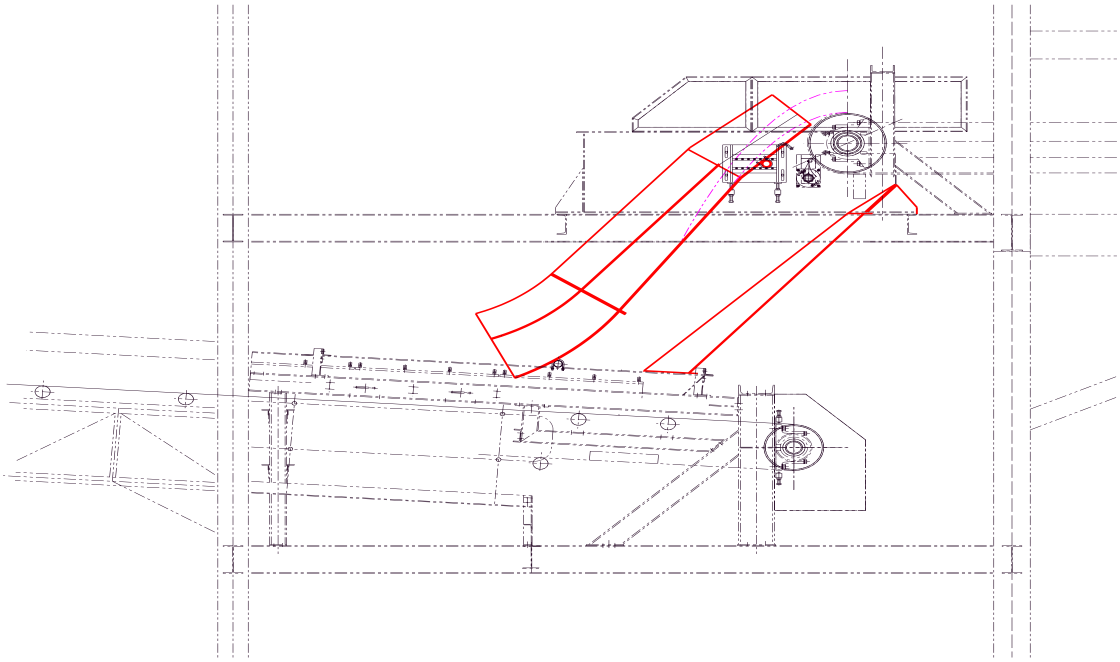

Figure 4: Chute arrangement at the tail end

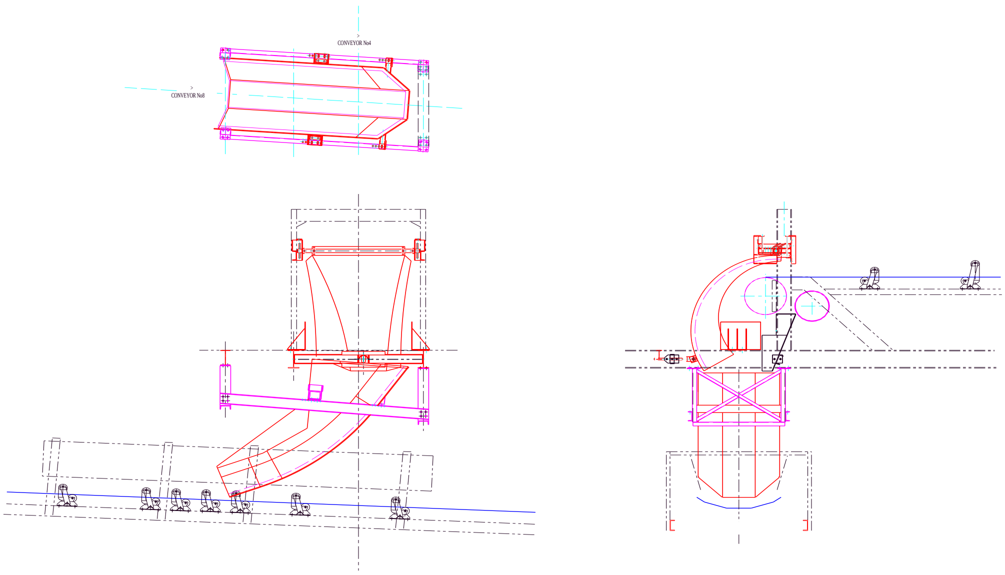

Figure 5: Typical chute arrangement at the head end

Directional changes in the above flowstreams are achieved by means of carefully engineered profiled plates. The loadstream is forced to change direction smoothly in curved trajectories rather than in straight paths.
The loadstream is concentrated at the same time in a narrowing channel, which enhances flowability and prevents the dispersion of particles. Momentum of the material is controlled through the transfer area and discharge onto the receiving conveyors is achieved with a velocity component in the direction of belt travel.

This new technology application prevents blockages, reduces fugitive dust levels and minimises particle degradation. A further benefit is the central loading achieved onto receiving conveyors, thus eliminating belt misalignment, belt damage and material spillages. The impact loading onto the receiving conveyor is minimised thus eliminating the need for impact idlers and the added benefit of prolonged belt life.

6. TECHNICAL DATA

Bulk solid		
Capacity	tph	1200 to 2000
Density	kg/m^3	900
Particle size	mm	less than 20
Moisture	%	20
Surcharge angle	Degrees	15

Belt		
Belt speed	m/s	3 to 5
Carry belt		
Material cross section	m^2	0.123
Belt width	m	1.05
Belt mass	kg/m^2	14.35
Belt thickness	mm	13.2
Belt top cover	mm	6
Belt bottom cover	mm	4
Belt strength	kN/m	250
Belt safety factor		10
Power Belt		
Belt width	m	0.4
Belt mass	kg/m^2	37
Belt thickness	mm	30
Belt top cover	mm	22
Belt bottom cover	mm	4
Belt strength	kN/m	1000
Belt safety factor		6.7

Idlers		
Carry idlers		
Rotating mass	kg/set	20
Pitch	m	2
Trough angle	Deg	45
Rolls in set	No	3

Roll diameter	mm	127
Middle roll width	mm	450
Load stream on middle roll	%	74

Return idlers

Rotating mass	kg/set	20
Pitch	m	4
Trough angle	Degrees	45
Rolls in set	No	3
Roll diameter	mm	127
Middle roll width	mm	450

Drive system

Motor type		VSD
Motor size	kW	160
Motor speed	rpm	1485
Gear ratio		5.4
Start factor (VSD)	%	120
Drive pulley diameter	mm	630
Lagging type		Ceramic
Lagging friction factor		0.6
Drive pulley wrap angle	Degrees	180

Take-up

Carry belt

Position	-		Tail
Type	-		Gravity
Belt tension		kN	18
Travel		mm	3000

Power belt

Position	-		Tail
Type	-		Gravity
Belt tension		kN	40
Travel		mm	3000

Horizontal curve

Carry side

Tilt angle required	Degrees	0
Belt drift inwards	mm	119
Belt drift outwards	mm	142

Return side

Tilt angle required	Degrees	8
Belt drift inwards	mm	55 to 104
Belt drift outwards	mm	0

7 COST COMPARISON BETWEEN A CONVENTIONAL SYSTEM AND THE POWER BELT SYSTEM

Extrapolation of the costs for the system at Lethabo indicate that on a conveyor approximately 20kilometres long there will be a Capital cost saving of R16million. The life cycle cost saving will be the cost difference between a steelchord belt and a fabric belt after 20 years.

8 COMPARISON OF THE PROTOTYPE PERFORMANCE WITH THE DESIGN PREDICTIONS

These preliminary results will be discussed at the conference as the plant is going to be commissioned after this report would have been printed.

9 CONCLUSION

Preliminary indications are clearly pointing to this form of long distance conveying becoming a reality, especially on high speed long distance conveying applications. The combination of lower capital expenditure as well as the reduced life cycle costs will favor this type of technology over other long distance conveying technologies.

10 AUTHORS

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Andries Wiid obtained a Higher Diploma in Mechanical Engineering from the Pretoria Technicon in 1985. He also obtained a Masters Diploma in Technology from the same institution in 1994. He then obtained a Masters Degree in Engineering (Bulk Solids) from the University of Newcastle & Wollongong in Australia in 1998. He joined Eskom in January 1981 and has worked in the field of Bulk Solids Handling since then. Presently his position is Chief Engineer in the Bulk Solids Consulting division at Eskom Enterprises T.S.I.

M Bagus (Presenter):

Muhammad Bagus graduated from the University of Durban Westville as a Mechanical Engineer. He joined Rand Mines in 1983 as an Engineer in Training. After 3 years at various gold and coal mines he obtained a Government Certificate of Competency (Mining) and was appointed as a section engineer at Middelburg Mine Services. He was responsible as a project engineer on the new mining section developments at Goedehoop and Klipfontein. He then joined Eskom in October 1993 and has worked as a consultant to Eskom Power Stations in the field of Bulk Solids Handling. He has a GDE from the University of Witwatersrand and is currently obtaining a MSc degree in Materials Handling from the University of Newcastle and Wollongong.

11 ACKNOWLEDGEMENTS

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ANNEX 1

General Arrangement of Power Belt and Carry Belt at the Head & Tail Ends respectively

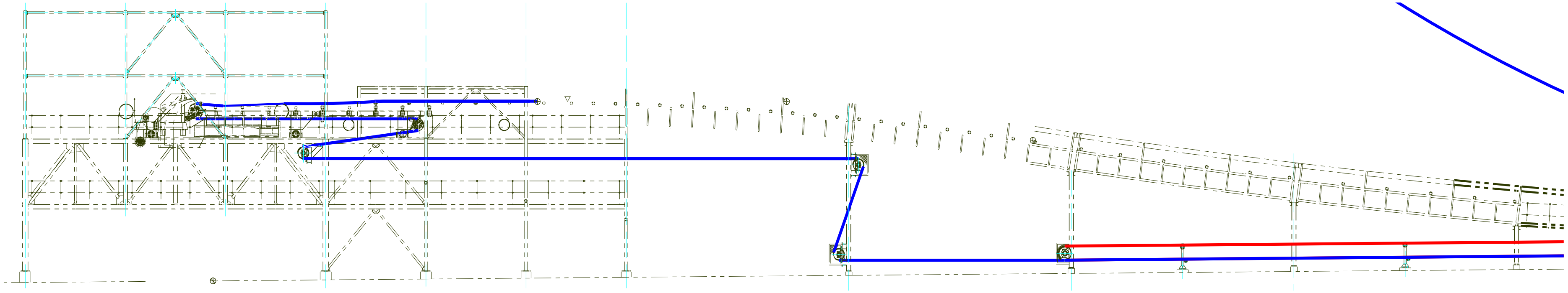


Figure 6: General Arrangement of Power & Carry belts at the Head End of the Conveyor System

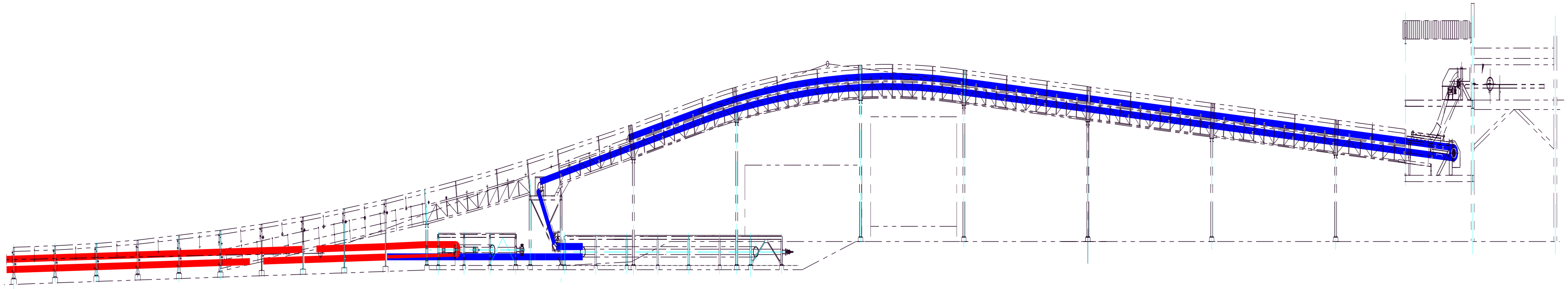


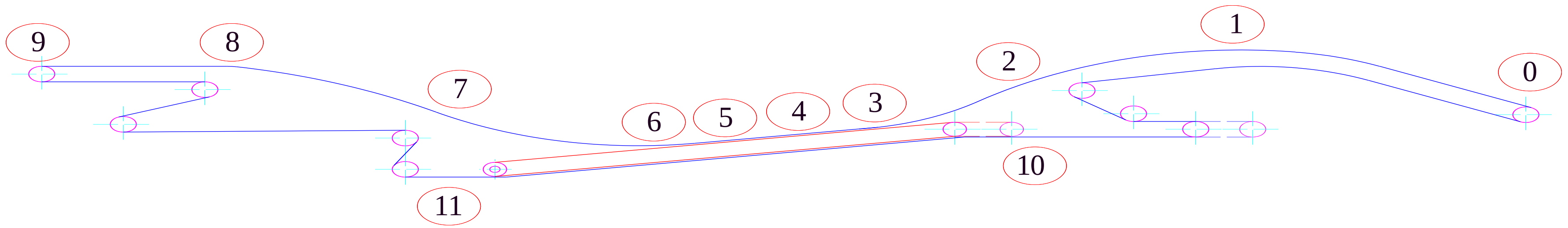
Figure 7: General Arrangement of Power & Carry belts at the Tail End of the Conveyor System

ANNEX 2

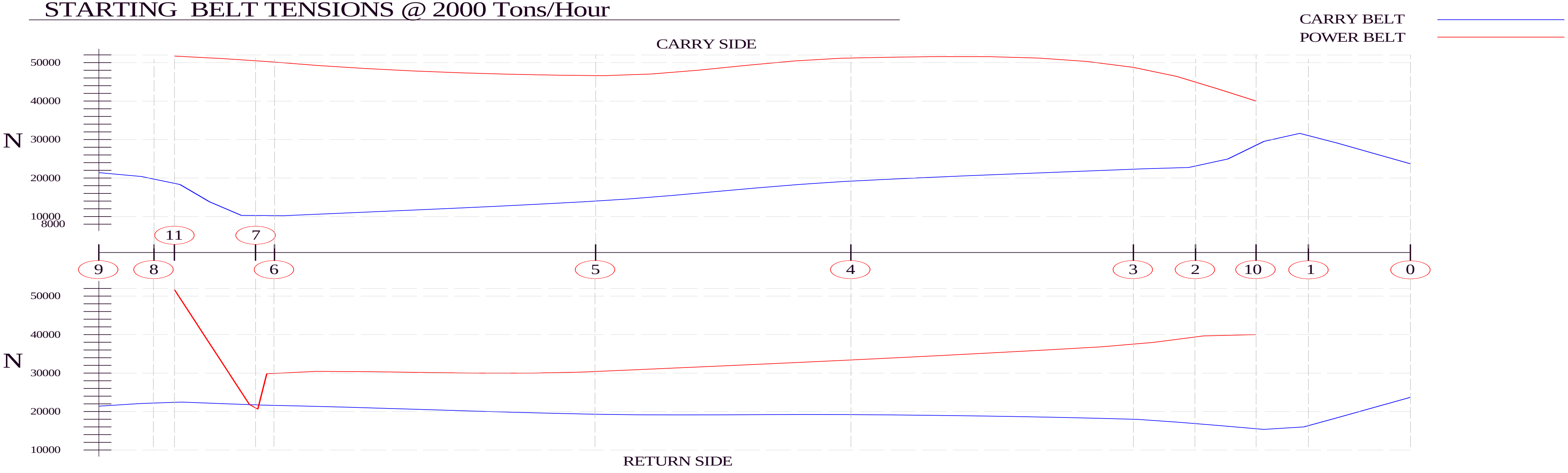
Belt Tension Distribution of the Power Belt & Carry Belt for a tonnage of 2000tph for :

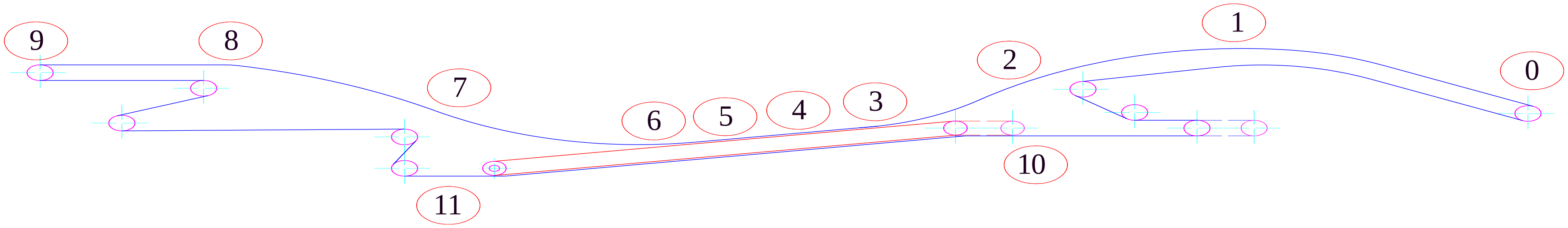
Starting

Static or Steady State Conditions
&
Stopping

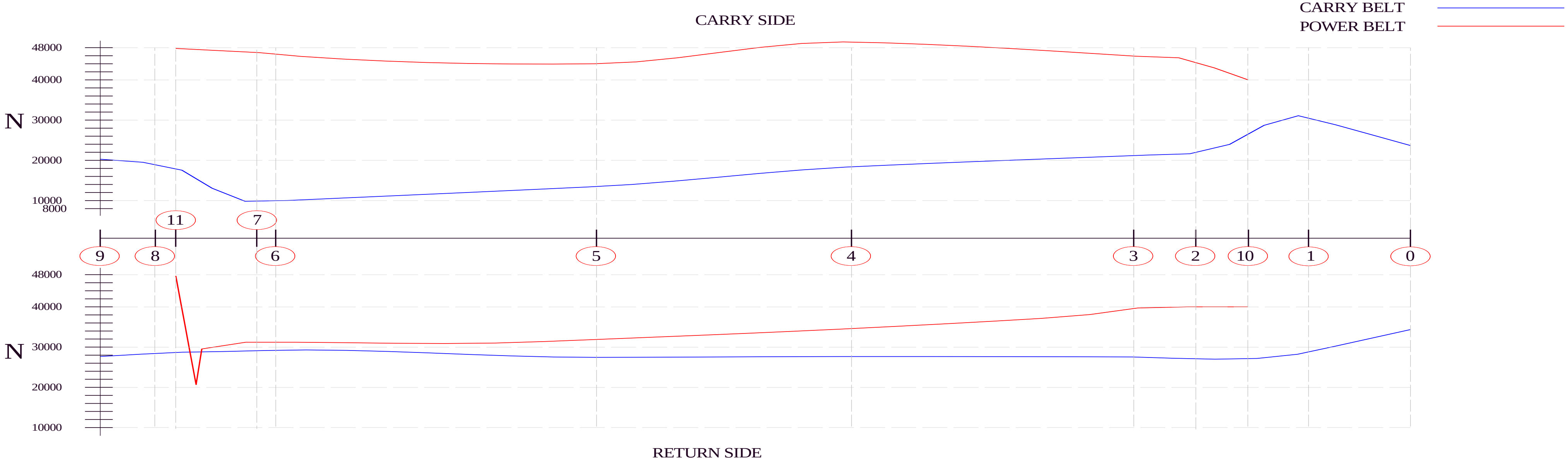


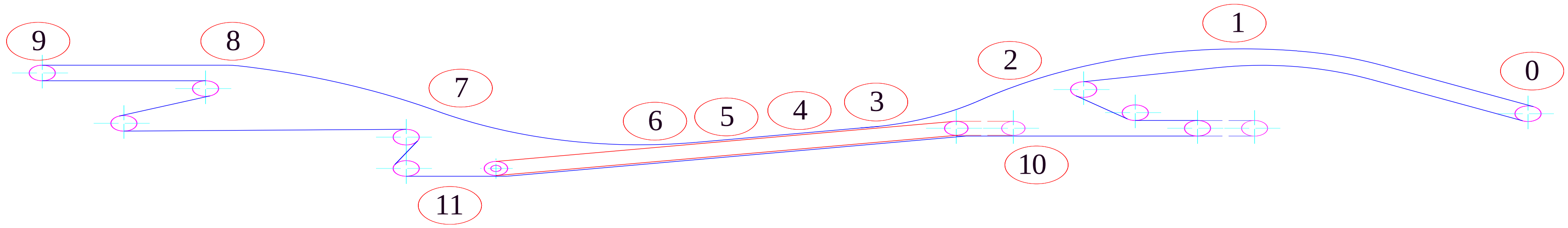
STARTING BELT TENSIONS @ 2000 Tons/Hour





STATIC BELT TENSIONS @ 2000 Tons/Hour





STOPPING BELT TENSIONS @ 2000 Tons/Hour