INTELLIGENT CONVEYORS

DYNAMIC ADJUSTMENT OF CONVEYOR SPEED UNDER VARIABLE LOAD CONDITIONS

BY

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INTRODUCTION:

The paper was assembled around Brandspruit Colliery, one of the five underground collieries in the Sasol Coal group. This group produced in excess of 40 million tonnes of run of mine coal in the last financial year with demand from customers constantly growing.

The case dealt with in this paper is hypothetical, although very close to the real thing. Facts and figures have been assimulated and do not necessarily represent specific mine information. This paper is based on problem scenarios for the mine with possible solutions to these.

The following information gave rise to the problem:

- Concentrated production sections.
- Increased demand from 7,5 to 8,5 million tonnes/annum
- Increased individual section per unit output from 800 t/hour to 1100 t/hour.
- Limited length and width of trunk conveyor belts.

Simulation models were used to enhance the decision making process. Variable speed will be dealt with in more detail later.

1 PROBLEM ANALYSIS

Most production facilities in a growing environment are faced with unique problems. The underground coal mine, on which this case study is based, is no exception. Normally, the engineer is faced with certain fixed limitations when production increases are required by growth in demand from existing facilities which in turn presents him with opportunities to innovate.

1.1 Production

The production of the mine historically came from three directions to an intersection at the twin conveyor inclined shaft bottom. Average production amounted to 7,5 million tonnes per annum. Two events have to be dealt with simultaneously:

i one of the three production areas is nearing the end of it's life, requiring the balance of production to be added to the remaining two production areas and

ii total production is to increase to 8,5 million tonnes per annum, the additional 1 million tonnes are to be allocated to the same two remaining production areas. Specific mine layouts and existing main conveyor installations as well as underground bunker positions further compounds the problem. This is mainly due to limited capacities of the current operational system.

If Layout 1 and Layout 2 are compared, it is clear that on Layout 1 conveyor systems are fairly well balanced as to individual share of production to be conveyed, in no instance more than four sections on any one trunk conveyor. On Layout 2, although, it becomes clear that congestion will take its toll, where up to 5 sections are starting to feed one trunk conveyor, in both areas.

The following table indicates the two scenarios, the current 1991/1994 and the future 1995/2000. Five sections are planning per unit production increase, while an additional section is added to fulfil the demand of 8,5 million tonnes per annum.

Production Sections	1991 - 1994 Scenario			1995 - 2000 Scenario	
	East	West	South	West	South
1	600 000				65 0000
2	900 000				90 0000
3		800 000		900 000	
4		900 000		900 000	
5		900 000		900 000	
6		600 000		600 000	
7		600 000		650 000	
8			800 000		90 0000
9			800 000		90 0000
10			600 000		60 0000
11			-		60 0000
Total Production per Area (million tonnes)	**1.5**	**3.8**	**2.2**	**3.95**	**4.55**
			7.5 million		**8.5 million**

1.2 Transport System

1.2.1 Belting

1.2.1.1 Width

The mine has deployed two widths of conveyors underground, 1 200 mm and 1 500 mm wide. With the exception of one trunk conveyor which is 1 200 mm wide, all other trunk conveyors are 1 500 mm wide. In both cases 152 mm diameter, 3 roll, 35° troughing idlers are used. All section conveyors, feeding trunk conveyors, are 1 200 mm wide.

1.2.1.2 Speed

The existing conveyors run at two different speeds, critical conveyors at $3,7^{m}\backslash_{s}$ and limited load conveyors, (ie. only up to 3 sections feeding) are running at $2.7^{m}\backslash_{s}$. These are fixed speed conveyors which run at these speeds irrespective of load condition.

1.2.1.3 Splicing

Normal clip splicing is used on most conveyors. Finger splicing has been tested on a few trunk conveyors with varying success. If finger splicing proves itself in the environment and further more be an economically viable option in the long term, it will definitely be employed on trunk conveyors, adding to prolonged life and lower maintenance life costs of the system. (in respect of rollers, scrapers etc).

1.2.1.4 Specification

Belting is all solid woven PVC, Class 1250. Average belt life on underground conveyors compared to surface conveyors which is running at a fraction of the cost, is a matter of great concern to the mine. In the quest to reduce life costs of conveyor systems, different types of belting are currently tested and specifications reviewed. (A pre-requisite is to ensure a sized product from the production sections to simultaneously reduce the possibility of external belt damage).

1.2.2 Hardware

1.2.2.1 Power Packs

Only two types of power packs are employed, 90 kW and 200 kW (multiple applications). These are deployed in various configurations, between one and four per conveyor drive depending on power requirements. Both types are further sub-divided into two ratios, each one giving a conveyor speed as indicated under 1.2.1.2. Currently only one manufacturer is used for power pack assembly, the gearbox manufacturer, although the soft start fluid couplings and motors are of different, but specified manufacturer. Power packs are of modular design, shaft mounted and torque arm supported to eliminate alignment problems totally.

1.2.2.2 Take-Ups

All installations are currently fitted with 2-speed electric winch take-ups which are giving satisfactory but not optimal control during starting and stopping of conveyors.

1.2.2.3 Power Supply

All electric motors powering conveyor belts are 1 000 V AC motors, started direct on line through soft start type fluid couplings to solid shaft mounted gearboxes.

All conveyors are centrally controlled on the surface through a telemetry system. The information regarding all conveyance parameters is available on a computer network on surface in every persons office fitted with a computer. (Thus, anybody on surface interested in, for example tonnage produced from an area for the shift at any moment in time may enter the window for the conveyance system and have the information on the screen immediately, also which belts are running and standing, bunker levels, motor currents and tonnes per hour).

1.2.2.4 Rolling Stock (Rolls, Pulleys, etc)

The mine has standardised on four types of idler rolls which offers tremendous long term advantages in terms of stock holding, control and user/supplier relationships. Troughing idlers for 1 200mm, troughing idlers for 1 500mm and V-return idlers for both applications.

Manufacturers of these rolls are constantly measured in terms of the quality of their product. Serious consideration is given to long term contracts with suppliers with built in continuous improvement measures in terms of quality, durability, supply and cost.

Only four types of pulleys are used on the conveyor systems, drive pulleys for

I 1 200 mm and

II 1 500 mm conveyors and

III other pulleys on 1 200 mm and

IV 1 500 mm conveyors

Only two types of bearings are used on these pulleys, one for drive pulleys and one for other pulleys. Standardisation advantages outweighs its disadvantages by far over the long term.

1.2.3 General Condition of Conveyor System

The general condition of the entire conveyor system at this mine is excellent in respect of availability reliability and cleanliness. Neat installations, with clean transfer points are common. Under these circumstances the introduction of new technology becomes just another step in the process of continuous system improvement and optimisation.

2 SOLUTIONS

2.1 Development of Alternatives

2.1.1 Governing Section Output

This alternative entails the integration of distances, belt speeds and the number of sections into a central control computer on the conveyor which may suffer from the effects of load piling. (Figure I). Simulation models showed a marginal improvement in production when the feed rate from each individual section is increased (as mentioned in the introduction) to the required levels and certain section feeds stopped for short periods in order to eliminate load piling and subsequent spillage. Although possible, this alternative requires extensive system maintenance/updating, due to the nature of an underground colliery operation, with continuous movement of sections, increase and decrease of conveyor belt lengths.

2.1.2 Double Conveyor Belt System

Double systems provide numerous advantages, esspecially with regard to the reduction of risk. The system offers flexibility in cases of poor availability. Initial capital outlay, long term maintenance cost, as well as energy consumption are some of the major considerations to be taken into account on this alternative. This alternative, if both conveyors were to be installed in a single roadway, presents a safety risk, due to limited access.

2.1.3 Wider Conveyor

The question that arises with this alternative is, "Where do we stop ?" The mine started out with 1 200 mm trunk conveyors which had to be replaced with 1 500 mm conveyors with the initial increased capacities/production some years ago. At this stage everything is standardised. This option, from an operational point of view, is very attractive, but simulation models showed that at expected production levels, the 1 500 mm conveyor is running at less than 50 % capacity on average. This fact triggered us to further investigation.

2.1.4 Faster Conveyor

This alternative has its limitations in standard equipment specifications. As previously noted (2.1.3), average capacity of the current system would entail that overall utilisation will decrease even further, which points to a total waste of energy for most of the time, as well as unnecessary centre conveyor belt wear and rolling stock wear. The current specification of rolling stock limits the possible maximum speed to 5 m/s with the resultant decrease in component life.

2.1.5 Variable Speed Conveyors

Depending on the level of organisational maturity with regard to control of technology, this option becomes viable. A further pre-requisite is the general condition of the systems and the level of maintenance of the conveyor systems. The following options within this alternative were considered :

2.1.5.1 Two-Speed Motors

Very simple technology with limited capabilities with regard to optimisation. Fluid couplings would still have to be considered for start-up as well as for low-speed to high-speed transfer.

2.1.5.2 DC Motors

Proven technology, maintenance intensive, very wide control window with excellent characteristics on conveyor applications. This type of drive is widely utilised across the globe on similar applications. The underground environment is not very friendly towards this type of system.

2.1.5.3 AC Variable Speed

Complex technology, but with significant progress over the last two decades. Successful installations are numerous in different applications and are becoming more and more common on conveyor belt installations. Control over a wide spectrum is possible, as with DC motors this option gives the advantage of being operated without fluid couplings, giving controlled start-ups and smooth speed change over a wide speed range. (Boundaries for this will be discussed later).

2.1.5.4 Switched Reluctance Motors

This option is very attractive due to the simplicity of motor design and the major advantage of a cold rotor, which means that the stator of the motor can be cooled very effectively since this is the only area of the motor within which heat is generated. The major disadvantage, unfortunately is the current support of this type of system in South Africa, which puts a damper on the initial excitement associated with the system.

2.1.5.5 Hydraulic System

Although hydraulics are very widely utilised on underground equipment, a severe resistance exists towards hydraulics at this facility. It is important to have the support of operational and maintenance personnel in a project of this nature. This option could be viable in future, but further investigation is required.

2.2 The Preliminary Decision

After careful consideration of the various options in a decision analysis, the preliminary decision taken was the route of AC variable speed. A number of critical criteria was taken into consideration in this decision ; a few of the most important ones are as follows :

Technology
Product support/Service
Delivery
Economy
Compatability

2.3 Control System

The following parameters will be taken into account in satisfying the need of production sections to produce at maximum levels, and to ensure the maximum life of components at minimum possible costs:

- Continuous production
- 100% System availability
- Optimal speed at all times
- Optimal power consumption
- Well trained maintenance personnel
- Minimum maintenance requirements
- Integrated PLC control

2.4 Advantages of Variable Speed

2.4.1 Effective Running Time (Utilisation) (Figure II)

Simulation models showed less than 50 % running distance of conveyor belting to carry the same tonnage of coal as opposed to a fixed speed of 3,7 m/s. (This is when the minimum speed is limited to not less than 1,5 m/s for purposes of effective electric motor cooling, not employing external means of cooling).

2.4.2 Power Consumption

Actual measurements showed that current conveyor systems consume up to 75 % of power, only to move the rolling stock, without load and this is again proportional to the speed of the belt. Thus, at lower speeds the power consumption will reduce accordingly. Maximum demand will also be limited during controlled start-up periods.

2.4.3 Component Life

With less than 50 % running distance of conveyor belting and consequent lower revolutions of the rolling stock, although mostly at full load, component life should increase significantly, since everything is any way designed for full load. A further spin-off is the reduction of shock loads on the system, especially during start-up.

2.4.4 Splicing

New systems will be installed with finger splices, which should reduce life maintenance cost, system downtime and enhance effective belt cleaning.

2.4.5 Take-Ups

Take-up movement will be reduced with the result that these units could be simplified, consequently making limited tensions in the belt system a possibility.

2.4.6 Degradation

As a result of the very specific requirements of our client, with regard to fine coal content, this type of system will have a positive effect on the generation of fine coal. Since conveyor belts will for most of the time run at full capacity, the cushioning effect of the first layers of coal on the conveyor will prevent the adverse generation of fine coal on transfer points.

2.5 Disadvantages of Variable Speed

2.5.1 Transfer Chutes

Initially these variable speed conveyors will feed into bunkers, thus with no difficulty in transfer points. Unfortunately, if these conveyors feed onto chutes, 90 ° or any other, these chutes might have to be adapted to accommodate the new set of circumstances. One possibility is active chutes, that is, a chute varying position/characteristics with the conveyor varying/changing speed.

2.5.2 Technology

Traditionally very simple, straight forward systems were employed underground. Underground conveyors were normally far overpowered to ensure reliability. This new technology requires a paradigm shift in the approach of operational, but more so, maintenance personnel. Highly skilled technicians and reputable back-up will be required to ensure reliable systems.

2.5.3 Initial Cost

Compared to simple traditional systems the initial cost will be between 25 % and 50 % higher.

2.5.4 Training

Significant investment in training will be required into maintenance personnel to ensure reliable systems, not only technical but also mentally to except and support the new technology, inside and outside the work place.

2.5.5 Maintenance

Maintenance of the system should not be more intensive than current systems.

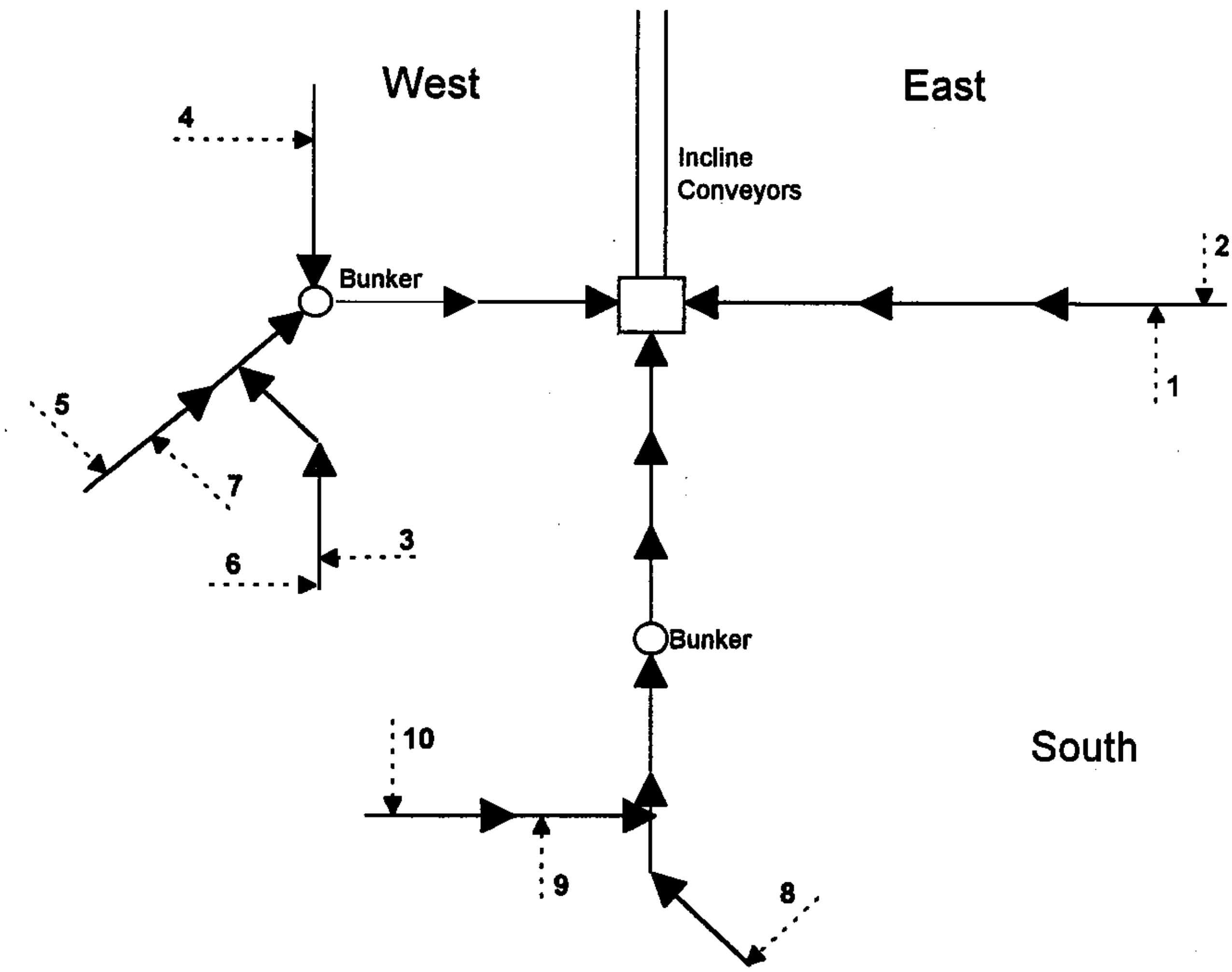
2.6 Summary

In a mid-life company, with a stable work force, this is the kind of step that might put some excitement into the organisation, outside of production sections, provided that the project is appropriately handled, that is with full involvement of all personnel right from the start, making everybody part of the experience in all its facets.

Variable speed seems to be the automatic choice to the problem presented. The advantages outweighs the disadvantages by a significant margin.

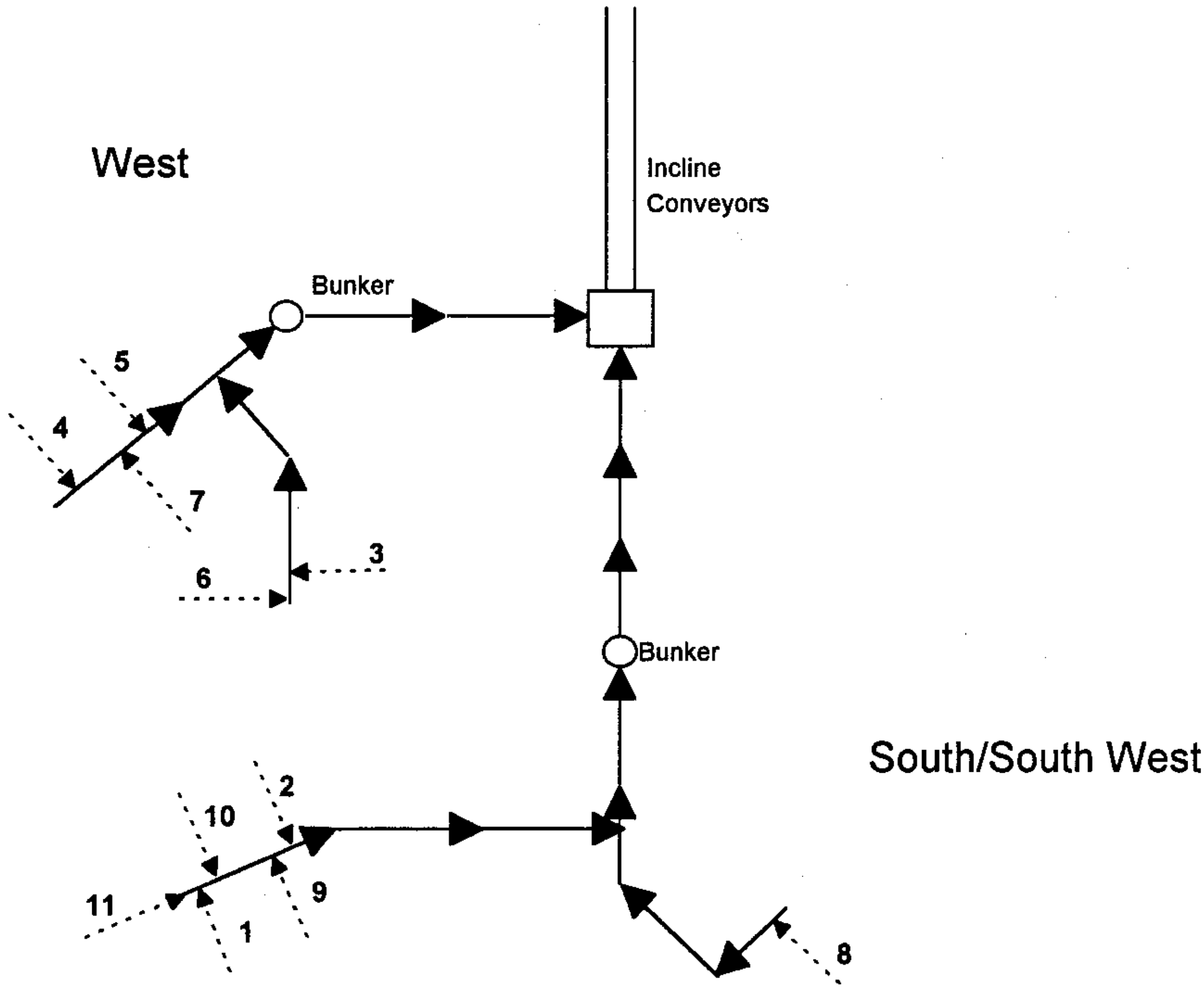
When successfully executed, this exercise will contribute to the quest for the continuous reduction of production cost as well as optimum utilization of assets at this facility.

Section Positions (1991 - 1994)



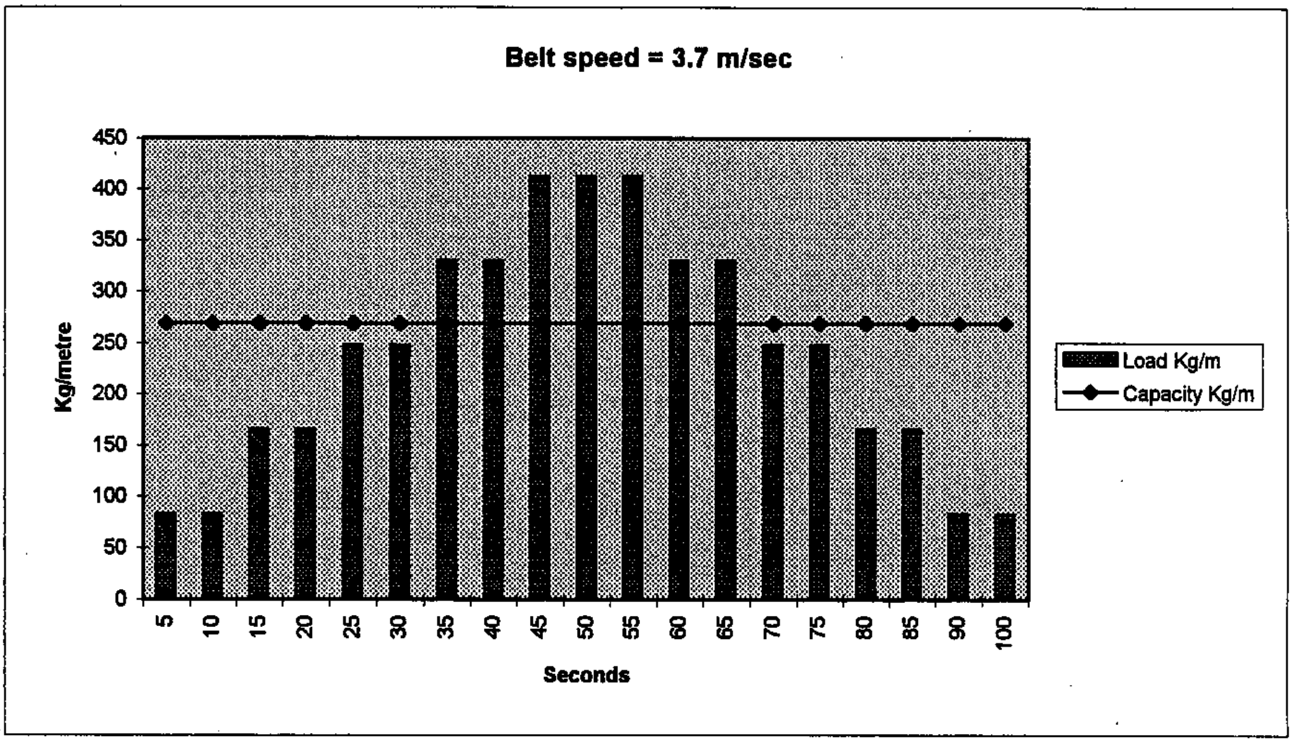
Layout 1

Section Positions (1995 - 2000)

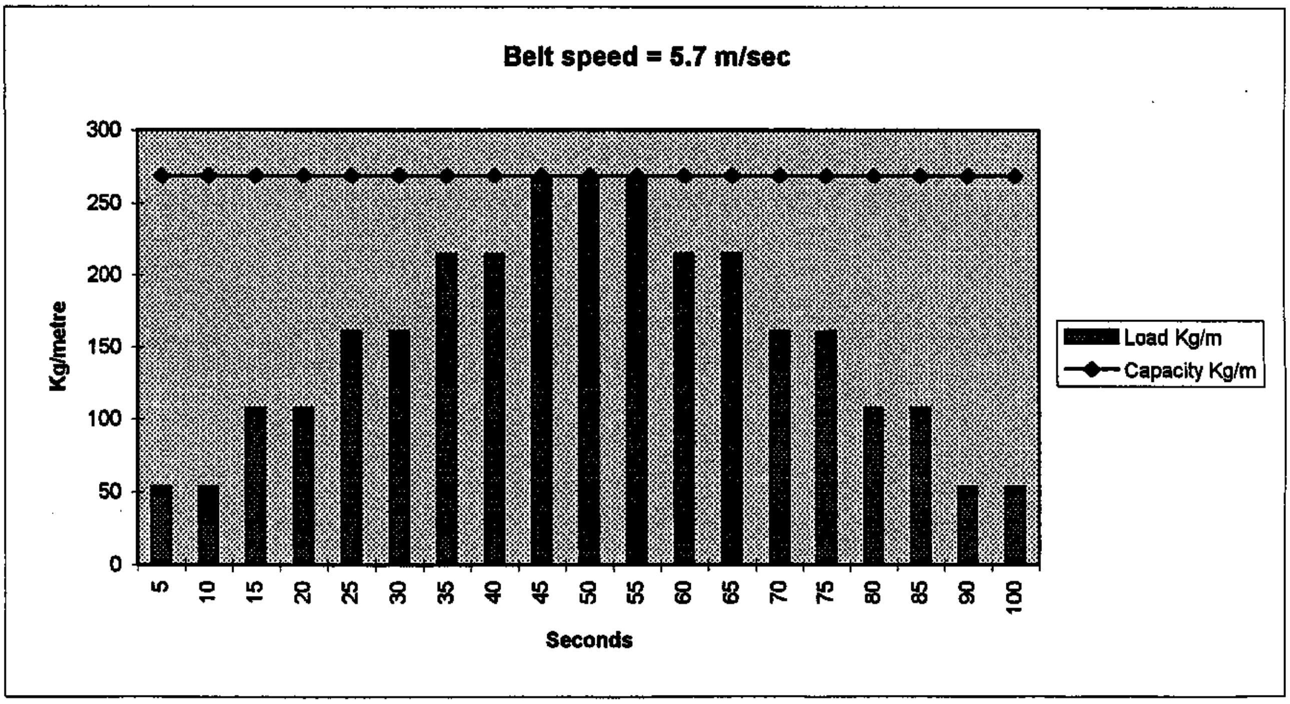


Layout 2

FIGURE 1



Belt speed = 3.7 m/sec
Kg/metre
450
400
350
300
250
200
150
100
50
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
100
Seconds
Load Kg/m
Capacity Kg/m



Belt speed = 5.7 m/sec
Kg/metre
300
250
200
150
100
50
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
100
Seconds
Load Kg/m
Capacity Kg/m

EVALUATION FOR EFFECT OF VARIABLE SPEED CONVEYOR BELTS

Capacity (t/h)	Conveyor Speed (m/s)	% of the Time	% x Speed
0	1.5	21.60%	0.32
1100	1.5	38.73%	0.58
2200	1.96	27.79%	0.54
3300	2.94	9.97%	0.29
4400	3.92	1.79%	0.07
5500	4.9	0.13%	0.01
		Average speed	1.82m/s