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BELT CONVEYORS - DESIGN, OPERATION AND OPTIMIZATION

PAPER B5

LONG OVERLAND CONVEYORS

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INDEX

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1. SUMMARY

The object of the paper is to put forward five main points regarding the use of long overland conveyors. These points are as follows :-

- Today there is a shortage of skilled labour combined with rapidly increasing power, labour and environmental costs. The long overland conveyor, although in some cases requiring an initially higher capital outlay, this is recoverable due to reduced operating costs.
- Reduction of required belt class due to suitable appreciation of dynamic starting considerations will substantially reduce initial capital expenditure.
- The preservation of belt life is a key factor in reducing maintenance costs.
- Steelcord systems are not comparable to external cable systems.
- The future of the long overland conveyor lies in improved understanding of Ky factor under practical circumstances and research into conveyor dynamics and multiple drive arrangements.

2. INTRODUCTION AND BRIEF HISTORY

Conveyors were in the modern context, first introduced using leather belts in 1795, followed by major developments during the period 1860 to 1880. Their use increased considerably following the introduction of the first steelcord belt by the Goodyear company in 1942.

When the opencast lignite mines commenced operations on the German Rhineland in 1950, they offered a unique field of application for conveying, leading to accelerated research and innovation emanating from that area. Another decade had to go by, however, before the small rate of extension (stretching) of the steelcord belt was appreciated as a major advantage leading to the usage of this type of belt for crossing long distances. It is symptomatic that the first belt exceeding four kilometers was only constructed in 1963 to replace a cableway.

The year 1970 marked the begining of a new era. The barriers, rather psychological than technical, to cross long distances were overcome with the construction of the longest conveyor in one length, 13 km, followed by 96 km in eleven lengths, of which the largest measured 11,6 km.

More recently in 1980, work commenced on an installation having a single head drive rated at 10 400 kW using a type St. 7 100 steelcord belt, the largest head drive up to that time being 3 000 kW.

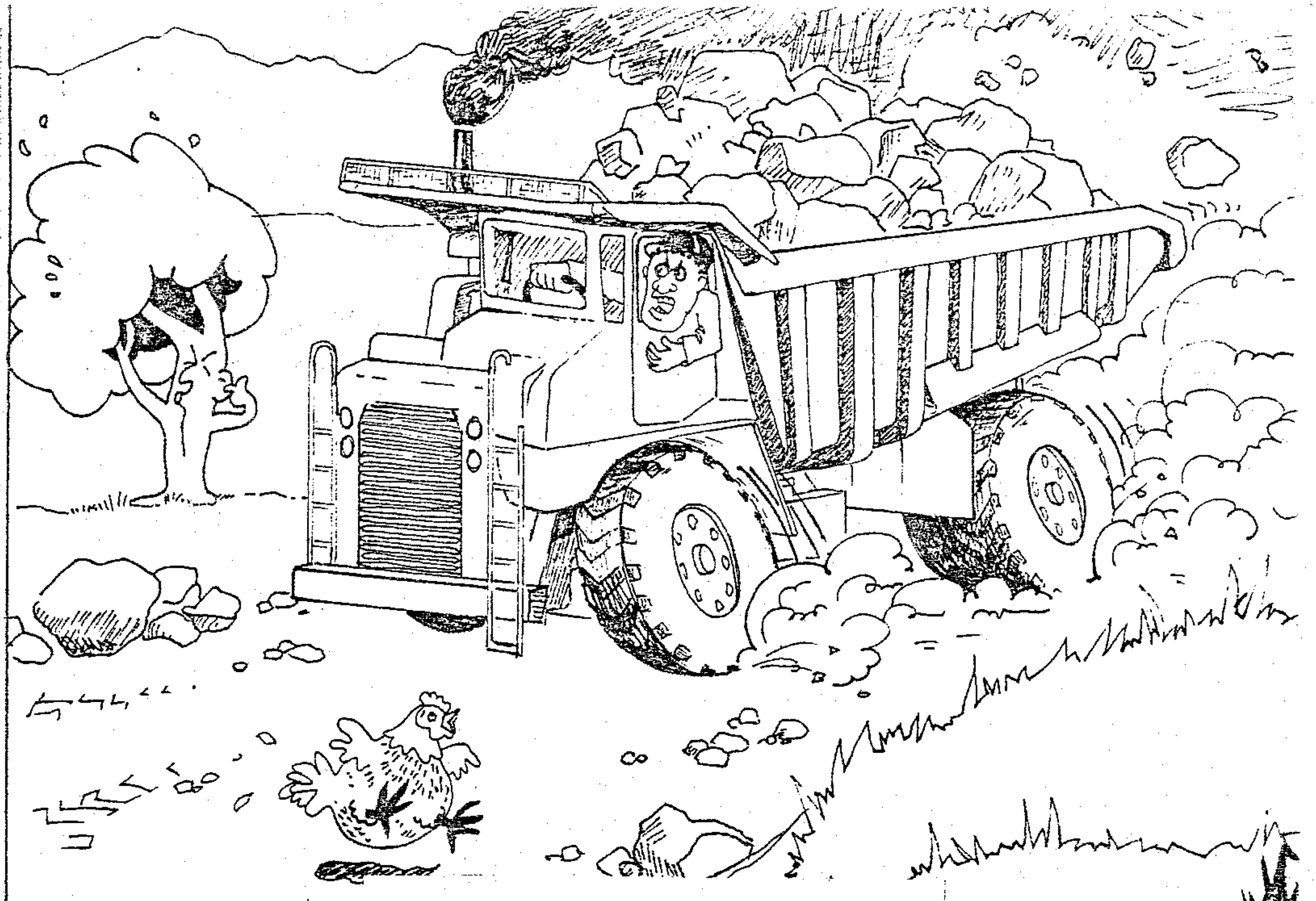
This drive, if applied to a horizontal application would permit a single flight of 50 km. This progress achieved by steelcord belt in a few years permits the 96 km distance crossed by eleven conveyors previously quoted to now be crossed by three or even two conveyors, one of which would be curved.

Belt conveyors have obtained their present popularity over discontinuous systems due to their many advantages such as almost unlimited capacities, economy, safety, versatility, reliability and satisfaction of environmental considerations. Times are changing, dramatic increases in labour and fuel costs have occurred over the last few years in conjunction with more positive environmental controls which have rendered the overland conveyor much more attractive to industry than in the past.

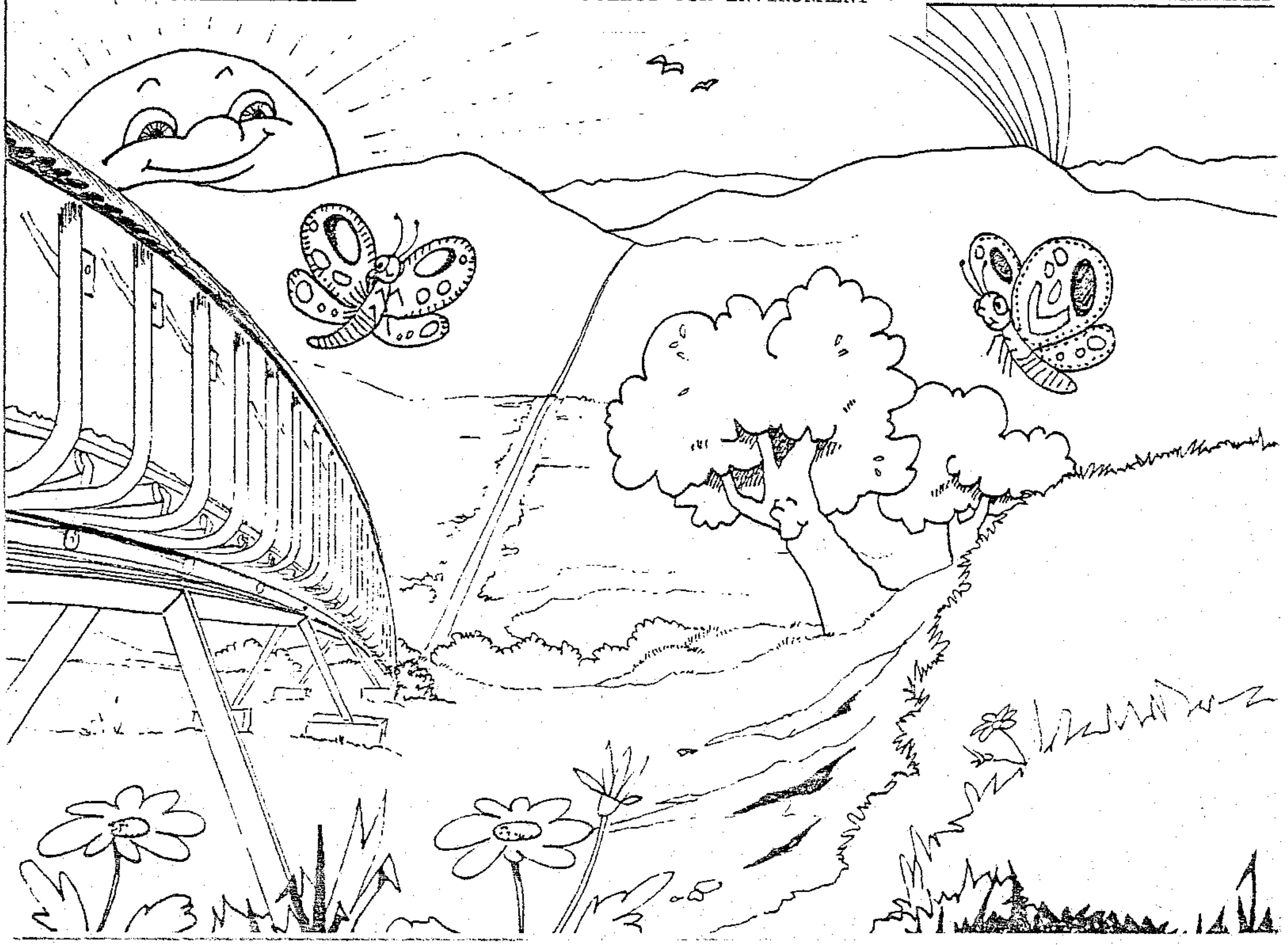
3. APPLICATION OF CONVENTIONAL CONVEYORS

It is not the intention of this section of the paper to go into detailed explanation of each different type of conveyor that is available. It is however the intention to put across the message that variations and developments from the conventional conveyor have reached such a degree that a materials handling problem can usually be solved in numerous ways with varying degrees of suitability. It is therefore the duty of the materials handling engineer to be fully aware of design of conventional conveyors, their application, and economics and therefore be in the position to give the best solution to materials handling problems.

The "unbiased" sketch overleaf and the conveyor/trucking cost comparison illustrate both the environmental problems associated with trucking and the operating advantages of conveying. In some cases, trucking has an initially high capital cost, but in every case, manpower and energy saving are dramatic.



CAN ENGINEERS NEGLECT OUR ENVIRONMENT ?



CONVEYOR/TRUCKING COST COMPARISON TABLE

This table illustrates comparisons showing operating cost savings incurred when conventional truck hauling was replaced by an overland conveyor.

YEAR RUN	CAP. t/h	LENGTH km	RISE +-	CONVEYOR H.P.	TRUCK H.P.	ADDITIONAL TRUCKING CAPITAL COST	ADDITIONAL TRUCKING MANPOWER COST	ADDITIONAL TRUCKING ENERGY COST
1963	620	4	+ 20	400	1 750	+ 15%	+ 85%	+ 77%
1969	1 000	4	+ 20	475	2 500	- 13%	+ 90%	+ 80%
1966	600	12,6	- 51	130	1 500	+ 4%	+ 83%	+ 91%
1970	1 100	2,6	- 51	160	2 500	- 37%	+ 90%	+ 94%
1970	800	13,2	- 27	1 900	7 000	+ 12%	+ 92%	+ 71%
1975	620	5,8	- 72	200	2 500	+ 22%	+ 90%	+ 92%
1979	1 000	5,8	- 72	250	4 000	- 21%	+ 94%	+ 94%
1980	516	11,2	- 557	50	5 700	+ 60%	+ 100%	+ 80%
1977	4 000	10,0	- 150	4 200	12 000	- 42%	+ 90%	+ 65%

4. ENGINEERING ASPECTS OF LONG CENTRE CONVEYORS

4.1 Belting

It is the vastly increased strength in the synthetic carcass and especially in steelcord belting that has given rise to the success of long overland conveyors. Steelcord classes of St 6300 are now commonplace, and using the generally accepted safety factor of 6,7 this represents an allowable tension in the belt of 940 kN/m. A 2,5 m wide belt can therefore operate, for example, at 2350 kN. St 7100 is at present considered the maximum class. In Europe, the safety factor is often taken as 5 with the resultant increase of possible tensions in overland conveyors.

Centre distances of the conveyors are therefore significantly longer thus increasing cycle time, even at higher belt speeds and therefore reducing belt wear. The life of a well designed long overland conveyor belt is generally taken as at least 10 years, but in practice, measured wear indicates that 20 years should be achieved, and indeed has been in some cases.

It is worth considering that the cost of the belt itself is generally of the order of 40 percent of the total value of the installations, and as such any reduction in the required rating is of economic interest. Start-up dynamics are critical to the belt rating. By the studied use of variable counterweights either via an adjustable tensioning winch or progressively increasing counterweight mass, tension requirements of the belt during start-up can be considerably reduced. As the conveyor starts, increased tension is applied by the winch or additional mass and is progressively reduced until the conveyor tensions are stabilised. This results in the partial elimination of high start-up dynamic tensions and corresponding reduction in belt rating.

As the replacement cost of belting is high, it is good practice to initially use the same bottom cover as top cover. This allows the belt to be turned over thus increasing its working life. In Europe, the recovering of belts in situ has become common practice and provides cost advantages where the carcass of the belt is sound, but the covers worn out. Many maintenance personnel overseas attach such importance to the preservation of the carcass that they continuously scan the return belt profile, monitoring and recording wear.

4.2 Idlers

The major development in the field of idlers is that of the suspended or "Garland" idler. Several advantages are obtained using these idlers including :

i) Very good belt training characteristics which is even more significant on shiftable or "snaking" conveyors.

ii) Increased elasticity to the start-up wave thus making starting of long conveyors more simple from the point of view of dynamics.

iii) They "may" be replaced while the conveyor is still running.

iv) Installation on horizontal pipes or even steel ropes is quite feasible for an inexpensive and easily de-mountable system as is often found underground.

As belt tensions increase so do the permissible centres on carrying idlers. It is not unusual in long overland conveyors to have idler centres in excess of two metres, providing the belt and material sag is such as to permit easy starting. I am aware of one particular case where the number of idlers had to be doubled to permit the conveyor to start.

Modern practice is tending toward the use of external idler bearings to permit ease of maintenance.

4.3 Drives

In general, the major decision which has to be made regarding the selection of the type of drive most suited to a particular steel cord installation is one of comparing the following :-

Single Head Drives : Advantage is that all major operating machinery is located in a central position and hence minimum maintenance, security and operating staff are required. This has to be balanced against the higher capital cost of such drive plus higher class belting, the higher cost of emergency spares and the increased technical skills of maintenance personnel necessary. It is, however, worth considering that internationally the trend, especially in large head drives, is to install units of a much higher quality without any attempt at standardisation. It has been found that the maintenance and breakdown times are minimal if this is the case.

Illustrated below is a table showing the maximum drive power of single head drive stations in kilowatts for steel cord belting with belting as a limitation.

Belt Width (mm)	Allowed Rating (kN/m)	Belt Speed (m/s)				
		2	3	4	5	6
600	280	225	338	450	563	675
750	280	300	450	600	750	900
900	700	800	1 323	1 764	2 200	2 646
1 050	700	1 029	1 544	2 058	2 570	3 087
1 200	876	1 472	2 043	2 944	3 680	4 415
1 350	940	1 776	2 664	3 552	4 440	5 328
1 500	940	1 974	3 948	3 948	4 935	5 922
1 650	940	2 172	4 343	4 343	5 430	6 514
1 800	940	2 369	3 553	4 738	5 923	7 106
2 100	940	2 764	4 145	5 527	6 910	8 291
3 000	940	3 948	5 922	7 896	9 870	11 844

Multiple Drives : Multiple conventional drives are commonly used instead of large head drives. They may be situated in combinations of head, tail and intermediate drive pulleys. This approach normally results in a higher number of maintenance and operating personnel of reduced training. The arrangement permits greater standardisation of smaller less sophisticated units and is particularly attractive in remote areas where spares and skilled personnel are not available. The economics of the system are a balance between the increased cost of the single drive and higher class belt versus the cabling etc., power consumption and personnel required for the multiple drive situation.

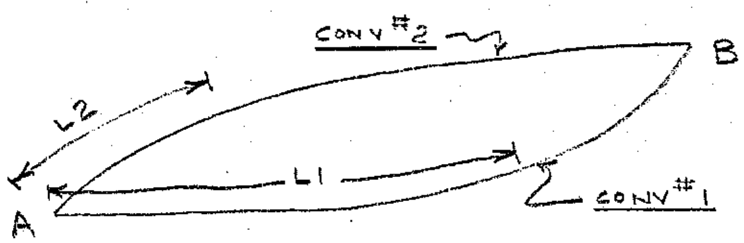
4.4 Loading

The loading of long overland conveyors is particularly important specially as speeds in excess of 2,5 m/s are normally dictated by economics. Essentially, the approach speed of the material should be the same as, or slightly less than the conveyor it is feeding. If not, the belt itself must supply the accelerating energy necessary, which results in excessive abrasion caused by belt/material interaction. To negate this, a speed-up belt fed by a conventional chute is normally employed. This allows such wear due to acceleration to be absorbed on an easily changed, short and cheap "sacrificial" belt. This belt also has the additional advantage of first exposing itself to any possible ripping due to sharp foreign objects being present in the feed. As it is short, it is much more sensitive to overload and can also incorporate belt rip devices. In this way the extremely expensive main belt is protected.

The pattern of material flow in high speed conveyors also changes. At speeds of the order of 6 m/s, some materials actually become fluid in appearance at discharge. The lined area has consequently to be much higher.

4.5 Power Requirements

It is generally accepted that there are various suitable methods of calculating the power requirements for conveyors, perhaps the most popular method being the one accepted by the Conveyor Equipment Manufacturers Association (CEMA). In this method, the absorbed power is directly related to the tension in the system by way of the "Ky" factor. This factor compensates for the power absorbed as the belt and material is flexed over the idlers and for idler inprint etc. The advantage of using this method can be easily demonstrated by considering two conveyors of identical lengths and lifts, but of differing routes as shown in the sketch below.



Despite both conveyors starting at point A and terminating at point B, the effective low tension lengths l1 and l2 are different. The additional power absorbed in l1 due to sag makes conveyor 1 absorb more power than conveyor 2.

The absorbed power of long overland conveyors can consequently be calculated to sufficient accuracy, but it must be remembered that the formulae determine absorbed power during normal running. Additional power is required to start the conveyor. There are examples of earlier long overland conveyors which have had numerous idlers removed purely to render them startable even after running-in. It must also be remembered that the factors in CEMA relate to conveyors of conventional speeds. The trend towards faster belts has given rise to research into how these factors are related to speed. Up to 3 m/sec one may assume the factors remain constant, but tests indicate that these factors should be increased by approximately 30% for speeds of 6 m/sec for example. Research is at present being pursued in Europe on this particular subject. Clearly then, for the design of long overland conveyors, the old practice of adding the power to raise the load added to the power to move the load horizontally added to the power to run the belt empty is inadequate for anything more than an in-plant conveyor. It should also now become clear that if one had one very large head drive resulted in high tensions, as opposed to a low tension intermediate drive system, the difference in absorbed power would be significant and calculable by formulae employing the latest Ky factors.

Having established what the true power requirements are to run the conveyor, and indeed to start the conveyor up, one must closely consider the drive pulley. Ideally the drive pulley should be small in diameter to increase rpm and hence reduce the torque, but for pressures created by the St. 7100 and 6300 belts with very large drives dictate very large pulley diameters (e.g. 2,6 m), with high shore hardness rubber. This is unfortunate in one respect, viz. the softer the rubber, the better the coefficient of friction. There have been many conveyors with drive slip problems solved by Linatex which is a soft latex rubber, but is limited to 1 kg/cm^2 and a belt speed of only 3 m/sec.

4.6 Protection

A conventional in-plant conveyor is normally equipped with an instrumentation package including underspeed switch, belt run-off switch, blocked chute detectors etc.

Long overland conveyors, however require additional mandatory protection viz. belt-rip detection. The higher belt speeds, long belt length, high belt class with consequent high cost per metre are all factors which make a belt rip a potential catastrophe.

The main cause of belts to be ripped is the jamming of damaging objects such as liner plates, rock drills etc. in the feed chute. To overcome this, there are essentially two methods that can be employed.

The first method is to instal a set of bars or in some cases wires between the impact idlers such that any object penetrating the belt will cause the bar to move or the wire to deflect. This activates a limit switch and trips the belt. Methods using impact of the conveyed material through the rip outs downstream impact plates with limit switches should be avoided, as sometimes the material does not fall through the rip, and also a liner plate can be jammed in a belt which is running empty.

The second main method of rip protection consists of inplanting continuous wire loops in the belt at regular intervals. An emitter induces a current in the coil which is then picked up by a receiver confirming continuity of the loop. The system has met with only moderate success to date, mainly due to the breaking of the coils due to fatigue and impact damage. Another disadvantage of the system is its cost which is very high, especially on a very long belt.

4.7 Starting and Stopping

As mentioned in the previous section on power requirements, one of the main considerations in the design of long overland conveyors is the prediction and control of behavioural patterns during starting and stopping.

The main problem here is that theoretical characteristics and actual conveyor behaviour do not always co-relate. There has been considerable investigation into this topic both theoretically and practically and the following basic conclusions may be drawn.

During starting the tension waves and subsequent drive torque variations give rise to instantaneous tensions throughout the system which may be estimated only and not as yet determined very accurately. However, the overall system behaves in accordance with Newtonian theory, and consequently starting and stopping times may be calculated to sufficient accuracy in the normal way.

To ensure then that the possibility of over-stressing is minimised, it is recommended that the theory as laid down in a paper by H. Funke entitled "The Dynamic Stress of Conveyor Belt Systems when Starting and Stopping" be employed.

5. CURVED CONVEYORS

When routing an overland conveying system, the designer is no longer as restricted, due to the now accepted use of horizontally curved steelcord conveyors. This problem has also to some extent been solved by the external cable system by means of constraining horizontal pulleys to flex the carrying cables. Flexibility, however, is lost as such changes can only occur at individual points, not curves, and each direction change will dramatically reduce carrying rope life. The only true curved conveyor belt system considered is therefore the steelcord.

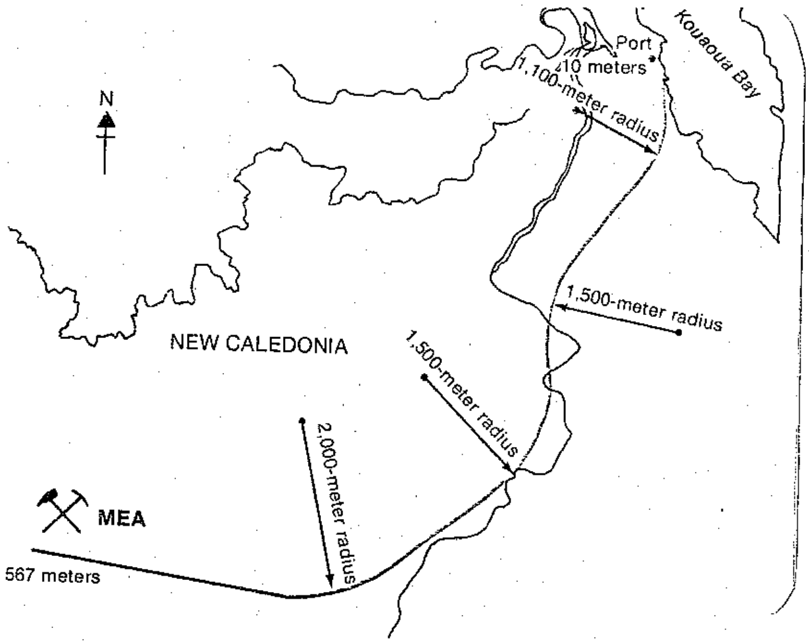
The problem with the installation of curved steelcord belts as opposed to externally guided systems is that the belt lies to a great extent unguided in the idler trough. When placing such a belt in a horizontal curve, constructional measures must be taken to prevent the belt running off the supporting structure due to components of tension, centrifugal, friction and mass forces under varying load conditions.

As modified garland idlers are largely self compensating they present little difficulty, but in the case of conventional fixed roll assemblies both complete and alternate differential tilting of the roll assembly is necessary. The exception to this is the employment of a tubular frame which follows combinations of vertical and horizontal curves with precision. Such tubular frame construction allows for the easy individual adjustment of both carrying and return idlers as opposed to tilting stringer lengths.

One of the most outstanding examples of this type of curved conveyor was installed by a French Company R.E.I. (Realisation, Equipments Industrials) in the nickel mines of New Caledonia, South Pacific.

This belt is a single 11 km flight with four horizontal curves as depicted overleaf.

The system operates on a two shift basis at a production rate of 560 t per hour, and replaced an existing fleet of 60 trucks resulting in a claimed transport cost saving of 80 percent.



The same company which designed and installed the above system now have the capability to design belts operating under similar conditions with radii of horizontal curvature of 300 m.

Although curved conveyors have obvious cost advantages, they are more resticted in terms of maximum speed than straight conveyors and hence their cost advantage per metre is less. Great care must be taken during the system evaluation stage to ensure the most economical solution for each application.

6. COMPARISON OF CONVEYOR SYSTEMS

Long overland continuous transporting of material can be broadly split into four categories, viz :

- By traction with large external steel cables supporting specially designed belts having longitudinal slots.

- by traction with a number of small steel cables incorporated in the rubber of belts having rectangular section.

- By propulsion, in pipes, of material maintained in suspension in a gaseous medium.

- By propulsion, in conduits of material maintained in suspension in a liquid medium.

The last two systems required preparation of the material to obtain their suspended state and decantation on completion of transport. In certain cases, intermediate stations are necessary to reactivate the suspension of the material transported.

Only the first two systems will be examined as they are based, in the long overland context, on established proven techniques and have in common the use of cables for traction.

The introduction of external steel cable driven belts coincided approximately with the development of steelcord belts and were a development by the manufacturers of overhead cableways and cables. Two avenues of development were explored, viz :

- A rigid belt moulded with longitudinal grooves into which the cables providing the drive and support are located. The belt is further supported by transverse steel bars which maintain the centre distance between the cables under load conditions thus preventing seperation of cables and belt. Material is transported essentially without troughing of the belt.

- A very soft belt forming a suspended endless bag which hooks onto the cables by its edge and so arranged that one side can be unhooked for offloading to discharge the material.

Both the above arrangements are relatively sophisticated and being specialised by nature dictate a monopolistic dependency on supply and maintenance spares. The use of supporting cables up to 56 mm diameter are subject to corrosion and constraints on bending and tension on support pulleys. Drive pulleys having diameters up to 6 m on friction drive wheels further complicate the installations. The capacities of external cable systems are at present, limited by a flat belt supply width of 1 500 mm.

Apart from the conceptual simplicity of steelcord systems their longlivety and long term cost advantages have been proven by an established vulcanisation lifetime of ten years, some belts having reached twenty years. The internal cables last more than fifteen years which I believe, is three times greater than any external cable system, even if utilising lined ropes. The internal cables are not spliced, their bonding is via the rubber carcass. Instead of a 50 m splice on a 50 mm cable, the length necessary for splicing a steelcord belt equivalent in tractive force is only one metre. (Splice length 1 000 x rope diameter).

It is my belief that, to remain competitive, the large external cable system has to reduce the factor of safety on operating tension rating to the order of 3, i.e. take a breaking risk which is 40 percent larger than minimum accepted practice on steelcord belting. The failure of one cable in an external cable system leads to instantaneous stoppage, whereas the breaking of several internal cables can await a programmed stoppage of less than a single shift duration. Components for steelcord systems are standard; largely interchangeable and manufactured on a competitive basis internationally.

The above comparison is largely confirmed by the market evaluation. I am unaware of any steelcord belt system having been replaced by an external cable system, whereas in France, for example, the eight systems in operation prior to 1960 have all either been abandoned or replaced. It is the shortage of such systems and their varying applications which makes it extremely difficult to objectively compare downtime, spares usage etc.

The NCB of Great Britian, traditional user till now of external cable systems, replaced one with a steelcord belt in 1977, and the reasons for this change are well documented. In 1978 the NCB took the important decision, in equipping their new mine at Selby, (output of 10 000 000 tons per annum) to install both an external cable system and a steelcord system, designed by REI in order to finally resolve the controversy within their organisation.

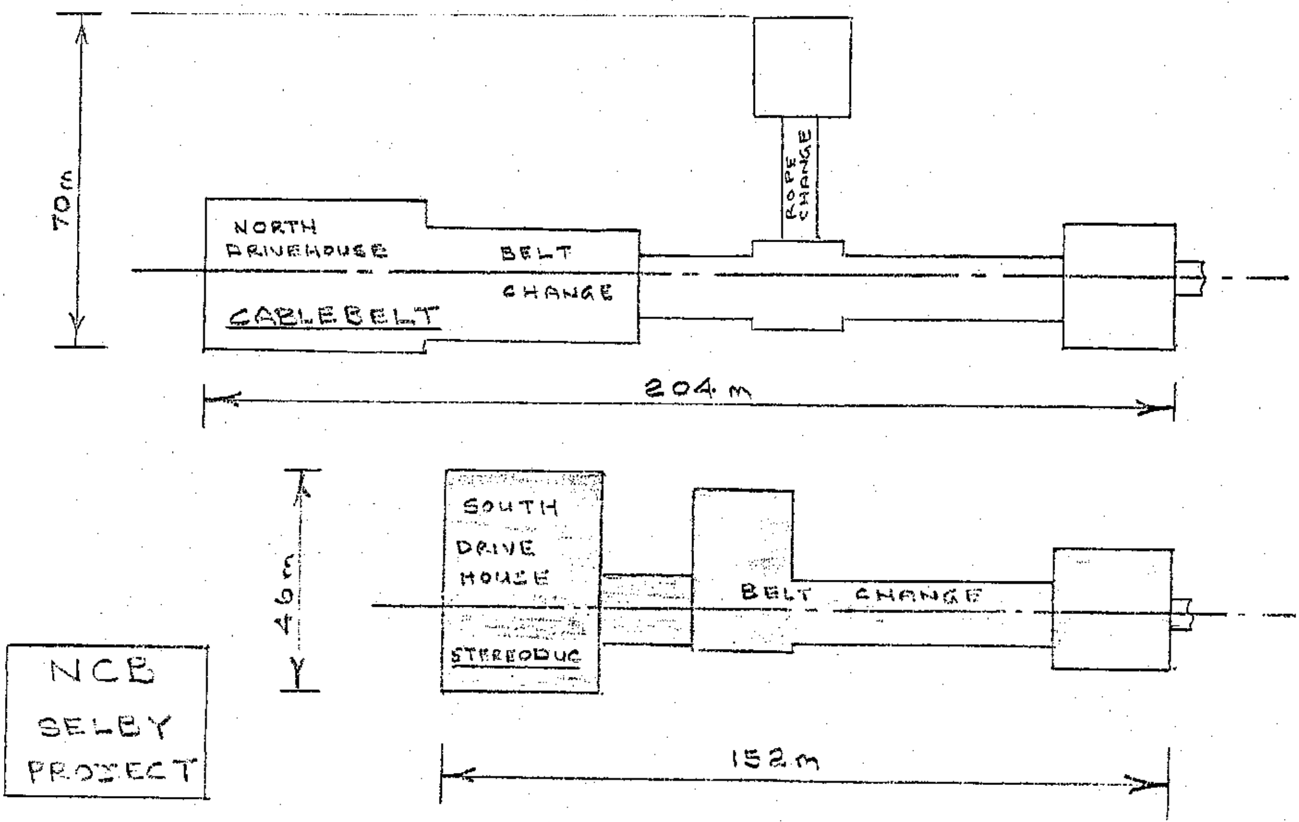
The design criteria of both systems are attached for the readers further consideration.

COMPARATIVE TABLE OF BOTH SYSTEMS OF 15 KM AT SELBY MINE UK

	CABLE BELT SYSTEM	STEREODUC SYSTEM	COMMENTS
General Characteristics	Length 15 km Elevation 1 km Max Capacity 2700t/h Feed Points 11	Length 15 km Elevation 1 km Max Capacity 3200t/h Feed Points 11	Both Systems identical Steelcord Capacity +20%
Head Drive	2 Friction pulleys of 6.7 dia with shaft dia 710 m	Single smooth head pulley dia 2,7 m with shaft dia 1600 mm	
Speed	Maintenance 2,2 r/min Service 7,4 to 22 r/min	Variable 0/60 r/min	
Differential	To balance the tractive force on each cable and accommodate pulley wear	0	
Reducers	One reducer of ratio 2,7/1	0	
Motors	2 off DC motors rated 4375kW at 60 r/min	2 Off DC motor rated 5050kW at 60r/min	4375 kW/2700 t/h 5050kW/3200 t/h
Belt	Carried on two longitudinal cables	Carried on standard idlers	
Construction	Special with low longitudinal grooves in V formation	Standard	
Shape	Totally flat by virtue of transverse plates 12 mm x 5 mm at 75 mm centres	Standard trough	
Material	NCB standard fireproof	NCB standard fireproof	
Width	1050 mm	1300 mm	
Speed	Max 7,6 m/s	Max 8,4 m/s	
Cables	2 exterior cables 57 mm dia	55 internal cables 13 mm diameter	
Cable Supports	Bogies having 8 300Ø pulleys at 4 m centres	0	
Breaking load	240t x 2 = 480 t	17t x 55 = 935 t	
Service Load	170 t	183 t	
Safety Factor	2,80	5,10	
Supports	Independant legs every 4 metres	Independant legs every 6 metres with 3 idlers of 168 mm dia	

Supports	Independant legs every 4 metres	Independant legs every 6 metres with 3 idlers of 168 mm dia	
Tensioning Belt Cables Drive and Maintenance house	 By Counterweights Two independant hydraulic systems 204 metres long	 By Counterweights and 250 kW winch 0 152 metres ong	1 system on SD, 3 on CB
Construction Schedule	First 2,7 km by 1985 Complete 15 km by 1988	First 5 km by 1982 Complete 15 km by 1985	

DRIVE AND MAINTENANCE HOUSE DIMENSIONS



7.1 Intermediate Drives

There are two schools of thought with respect to the use of intermediate drives for long overland conveyors.

On the one hand there are the following advantages :-

- Much lower belt classes may be used.

- Shorter radii of curvature may be incorporated and the conveyor may MORE closely follow the terrain.

- Improved starting characteristics can be obtained (sometimes).

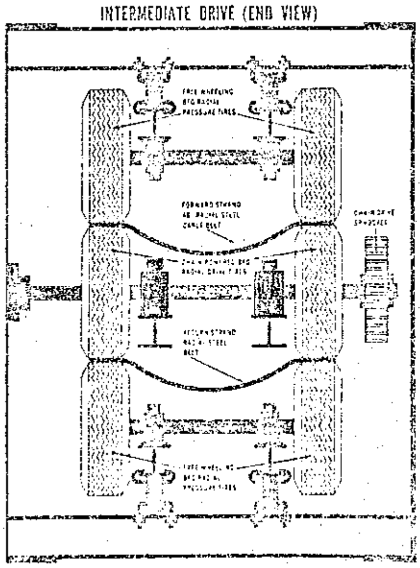
- By virtue of the multiple nature of the drives, the optimum number of drives may be used for any specific tonnage to be conveyed, and a breakdown of a drive unit will not stop production.

- Utilisation of the return belt for bulk conveyance is facilitated.

The main disadvantage of a conveyor system incorporating intermediate drives is the dramatic increase in the number of maintenance areas, and extra electrical and instrumentation work involved. To this end, various European companies prefer to design very long overland conveyors with one single massive head drive.

It is interesting to note however, that research into intermediate drive systems continues, and according to B.F. Goodrich, their multiple tyre I.D.S. become economically viable with conveyors of over 3,2 km centres. A typical drive arrangement of this system is shown in the sketch below.

INTERMEDIATE DRIVE (END VIEW)



This system utilises the return belt for material conveyance, and was developed by Goodrich and Continental Conveyor Co. A 4,4 km centre example of this system may be seen at the American Cyanamid Corporation in Florida. Phosphate material is conveyed at 2500 t/h from the pit to the plant. By inversion of the return belt, the plant tailings are returned to the pit on the return strand at 1400 t/h. The effective length of the conveyor is therefore 8,8 km.

In this application the intermediate drives are 149 kW each and are positioned at optimum points with respect to belt tension, and spaced up to 914 m.

Each drive module uses 12 radial ply tyres. Should the return run not be utilised, one third of the tyres are replaced by ordinary pinch rollers.

Other systems which do not employ tyres at all have also been developed. One is the intermediate drive belt which is effectively a drive conveyor within the main conveyor, and another is a system incorporating motorised idlers. The initial results from the former are quite favourable, but it is clear that further research work and economic studies must be carried out before sound conclusions can be drawn. Should the individual require further information, then papers on the subject are available on conclusion of today's seminar.

7.2 Utilisation of Return Belts

When one is faced with an inport/export situation either by a product/raw material or harbour requirement, then the possibility of utilising the return belt to carry material should be considered.

Although the Goodrich system, as outlined in Section 7.1, lends itself particularly well to that situation, conventional head and tail drives will achieve the same result. The obvious advantage is a much greater utilisation of capital related to tons transported.

At this stage I should like to thank M.H. Bocchietti of REI in France for his assistance in supplying detailed statistics for inclusion in this paper and the benefit of his vast experience.

Copies of papers on the above subjects are available for further study, and a list of such papers is appended.

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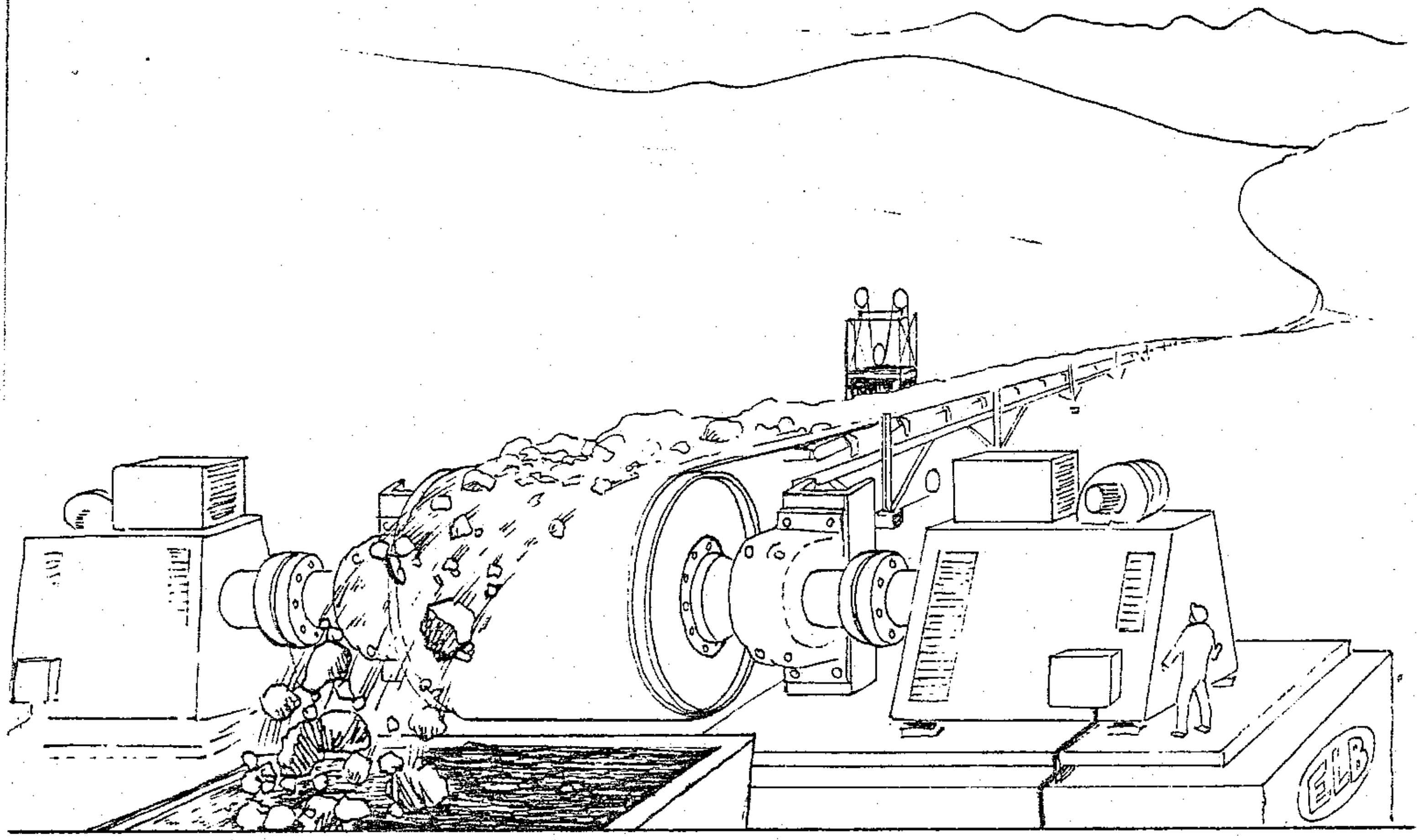

WHERE DOES THE FUTURE LIE ?