INTERNATIONAL MATERIALS HANDLING CONFERENCE

BELTCON 3

Conveyor Belt Monitoring as a Developing Art

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9, 10 & 11 September, 1985
Landdrost Hotel
Johannesburg

The S.A. Institute of Materials Handling
The S.A. Institution of Mechanical Engineers
The Materials Handling Research Group (University of the Witwatersrand)

CONVEYOR BELT MONITORING AS A DEVELOPING ART

S Y N O P S I S

Testing of Steelcord belts by magnetic/electrical methods is a new technique recently introduced from Australia. The paper describes how the method has been developed in this country to include systematic tracking measurement. Also how the improvements, in cord break data are incorporated with other parameters to give complete estimates of life for a given belt. It is demonstrated that belt life can often be controlled and significantly extended. Many actual data records from Southern African belts are presented together with feedback on the way in which scanning programmes are being utilised most successfully by steelcord belt users.

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2.0 INTRODUCTION

In 1983 a new system of condition monitoring for steel cord belts was introduced to this country.

The service had been operating in Australia since 1981 where it was invented by staff of the CSIRO and developed by an Australian company set up for the purpose.

At that time the process described at the last Beltcon conference was regularly detecting loss of net steel mass from the carcase, net cover thickness along the belt length, cover wear profile and thickness across the belt at selected points and splice lay-up. Operating on a given belt at 6 month to 24 month intervals.

The signal is the result of exciting the cords in the belt magnetically and recording the functuations caused by changes in belt properties. Presentation is via a pen chart recorder. By gearing chart speed to belt speed and given the distinctive signals produced at splices any given feature can be directly related to its position along the belt.

The purpose of this paper is to indicate how the service has been extended since its introduction in 1984, patterns of use in this country and developments overseas. We also wish to feed back to the industry the first indications as to patterns of behaviour in actual steel-cord installations. This data comes from 34 local scans performed to date and will be extended in coming years to form an information databank.

Except where noted all the information in this paper is from local sources.

3.0 THE GENERAL METHOD

3.1 Longitudinal trace presentation

Fig 1 shows a typical trace coming from the monitor. The horizontal axis is proportional to distance along the belt. The vertical axis is a measure of a property of the belt. Net effects are summed across the belt. This record has two syncronised traces to show related effects - in this case mass loss and cord breaks.

A calibration is provided which relates to the particular belting recorded. Note that a single cord loss in this case, represents approx 1% of total mass.

3.2 Mass related effects

Referring to the shaft belt in Fig 1 we can see a variety of features typical of such mass records.

- 3 A splice with its extra mass in the overlap
- I A loss due to corrosion of approximately 3 cords equivalent
- V A loss due to edge damage with trailing cord end
- II A loss due to edge damage with leading and trailing cord ends. Approximately 5 cords in extent.

We can use this same technique to explode the splice. By spreading out the time-base we get a record of the lay-up. Fig 2 shows a variety of normal splices. The profile ringed is typical of good lay-up practice for one-step, two-step and three-step splices respectively. Dimensions A and B give measurements of the peak mass and splice total overlap respectively, together these indicate the total steel area in the splice. Given good bonding this

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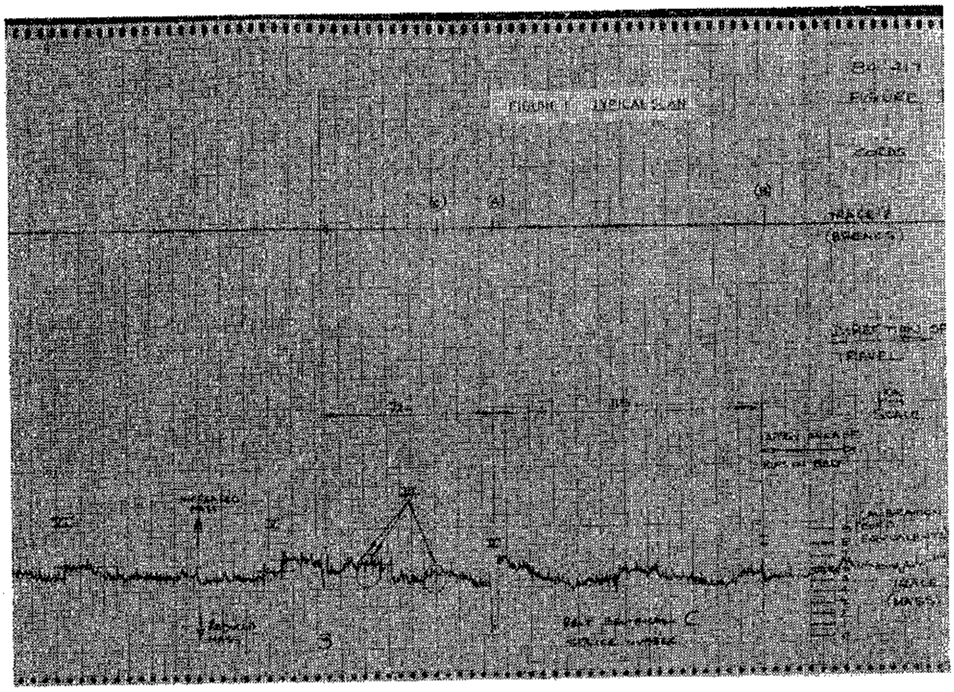


FIGURE 1 TYPICAL SCAN
84-417
FIGURE
TRACE 1
(BREAKS)
TRAVEL
SCALE

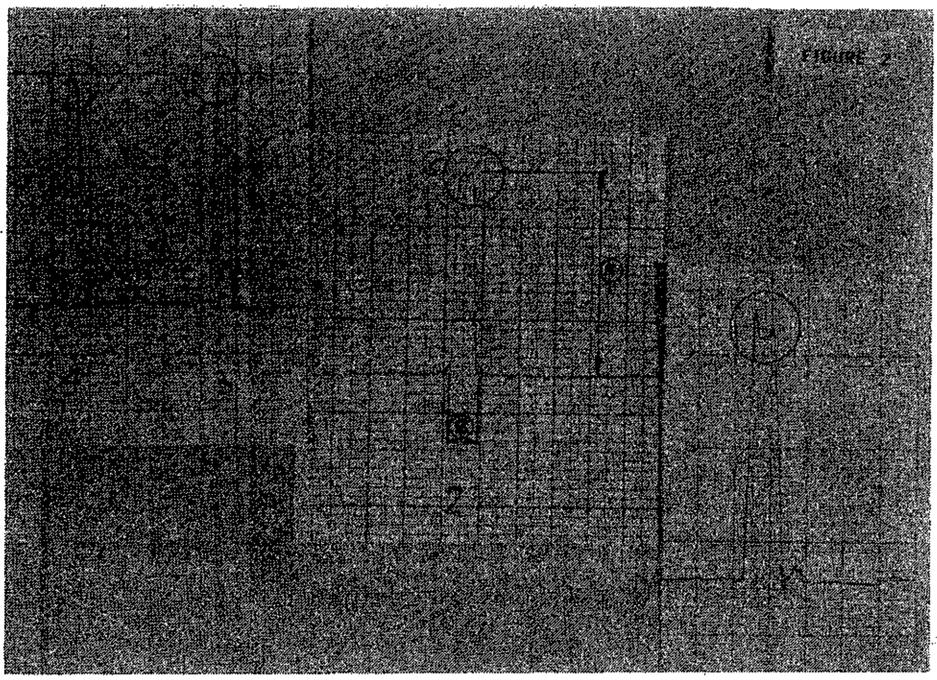


FIGURE 2

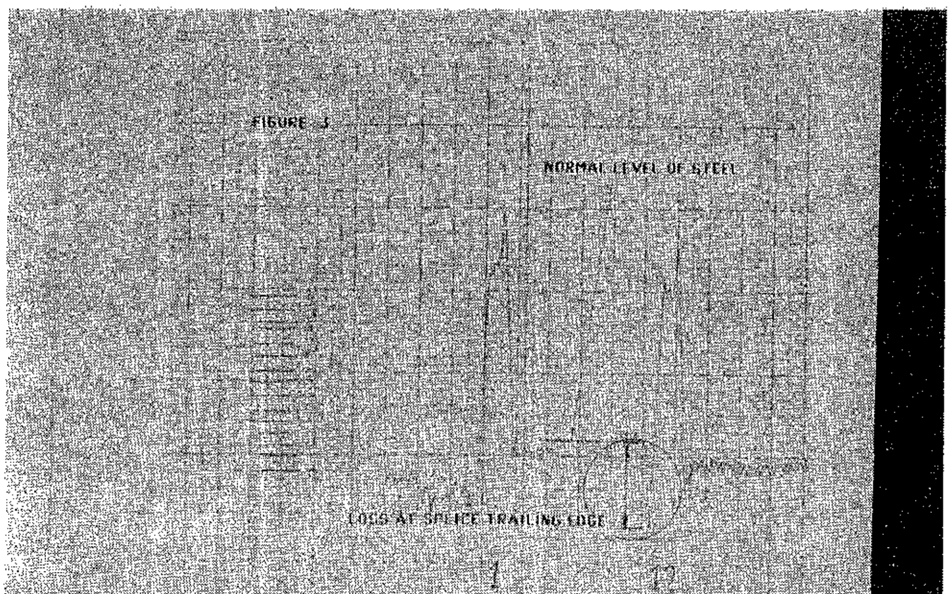


FIGURE 3
NORMAL LEVEL OF STEEL
LOSS AT SPLICE TRAILING EDGE

is related to splice strength. Unfortunately a method of direct bonding strength measurement is not available at this time.

By contrast, Fig 3 shows a splice having an abnormal lay-up. Fig 4 shows a static X-ray of the marked splice edge, taken over the whole width of the belt, for information. This confirmed the indicated loss of belt mass - thus strength - and highlights the exposed leading edge cords which hold major damage potential. The assymetry of the splice was exposed by manually recording the tracking characteristics of the belt.

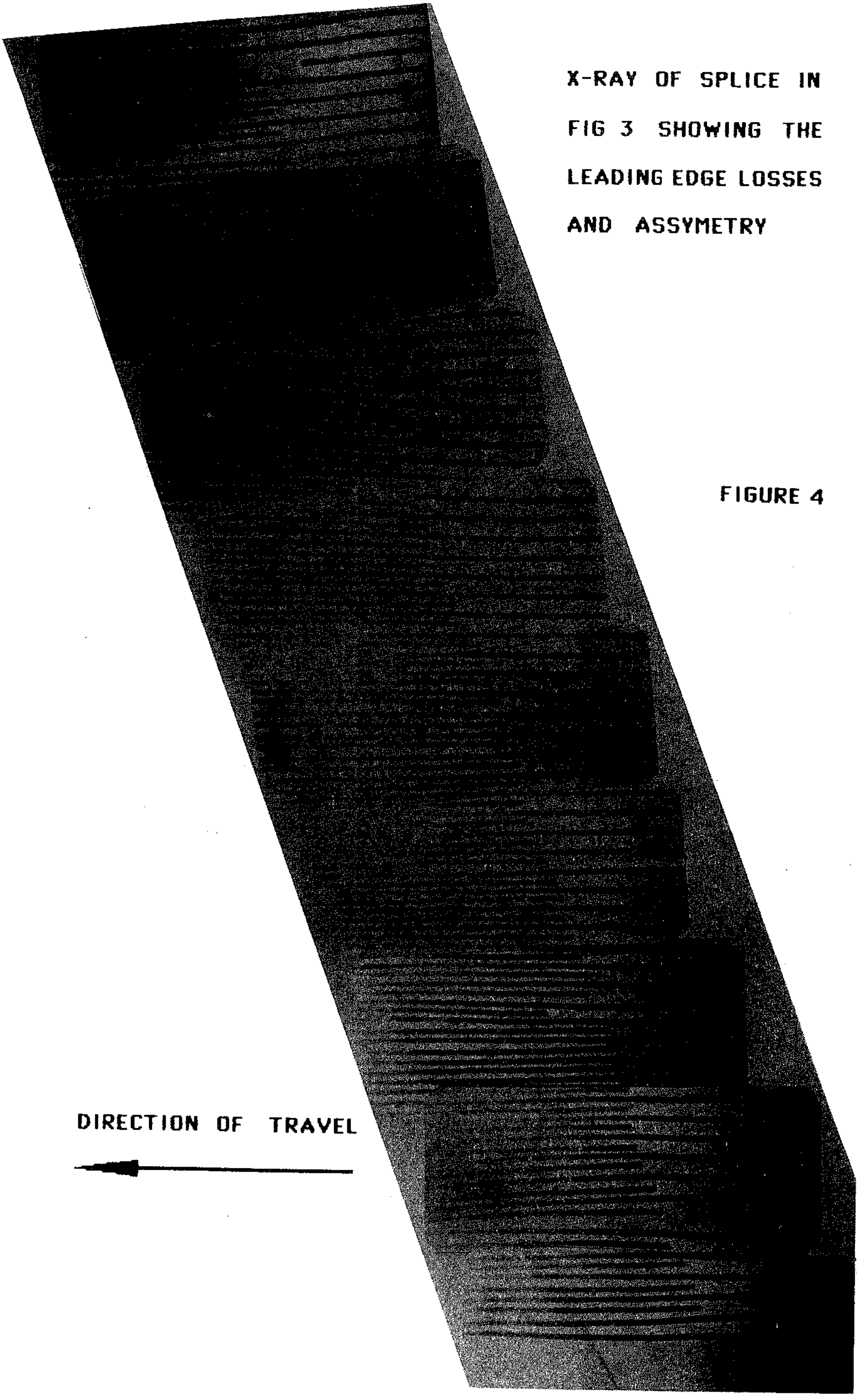
3.3 Thickness related effects

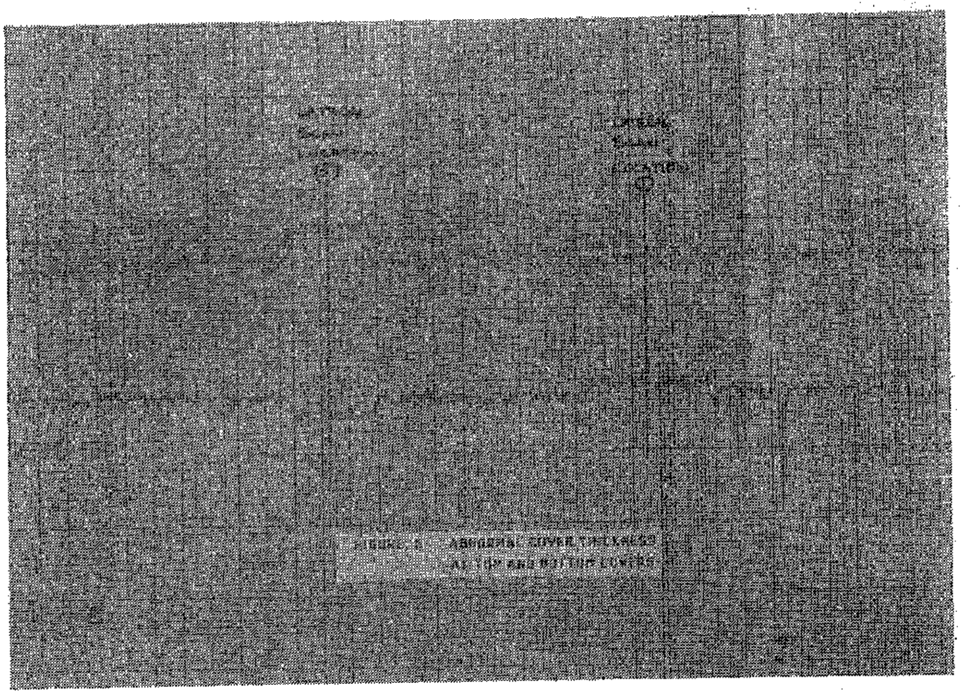
By changing the signal production and sensing we are able to isolate belt cover effects (1,2) The result is a trace such as Fig 5 from a shaft belt only a few months old. The upper trace shows top cover net thickness and the bottom trace, pulley cover. At location (2) the belt was found to have inverted covers for 35m of belt section B. This belt had an extra thick bottom cover(approx 7mm) fitted to protect rip detection loops, fortunately the scan also showed that the reduced (approx 5mm) cover did not coincide with any loops.

The thicknesses are found by an additional technique of "lateral scanning" using a hand-held probe. Fig 6 shows such a scan. The trace covers the full width of the belt at a position selected from the net cover data. All scans are repeated (4a and 4b) to detect any inconsistencies of technique. The peaks on each trace represent the top of each cord and the rubber over each cord is measured by referring to the calibration. In this case average belt

X-RAY OF SPLICE IN FIG 3 SHOWING THE LEADING EDGE LOSSES AND ASSYMETRY

FIGURE 4





ABNORMAL COVER THICKNESS AT TOP AND BOTTOM COVERS

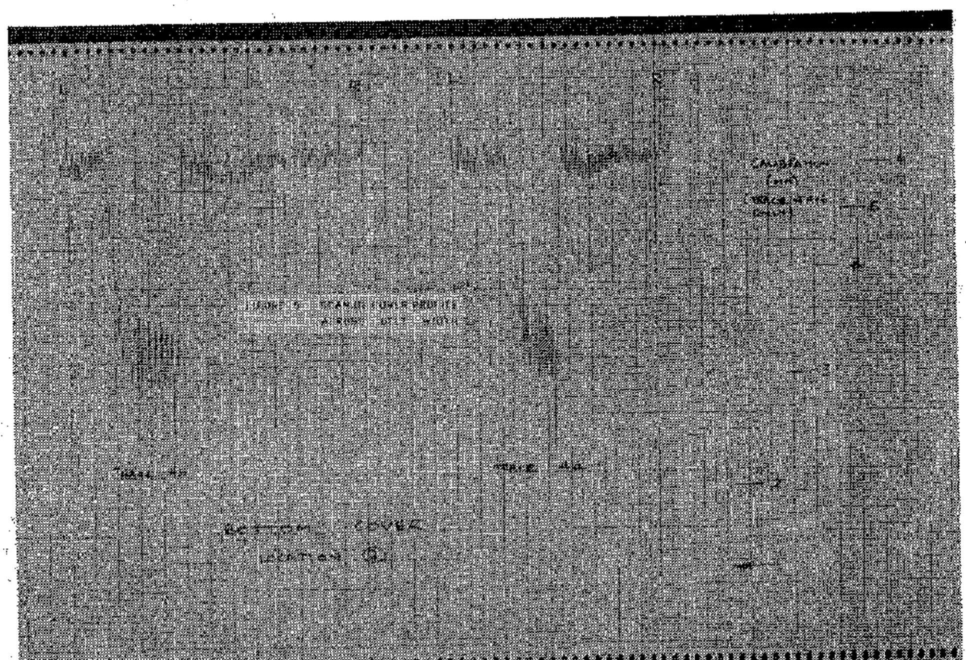


FIGURE 5 COVER PROFILE

thickness is 6mm, but a large proportion of the belt is below 3,5mm thick. The significance of this will be discussed later.

3.4 Complementary systems

Two fundamental points must be made. Firstly, Magnetic/Electrical monitoring measures effects which change slowly. It is not and cannot be a replacement for rip detection and similar on-the-belt safeguards.

Secondly, the system provides an insight into the structural and constructional state of a belt. Since the measured effects are largely not visible, certainly at fly speed, it complements and not replaces regular visual inspection.

How these techniques complement one another will be discussed in later chapters.

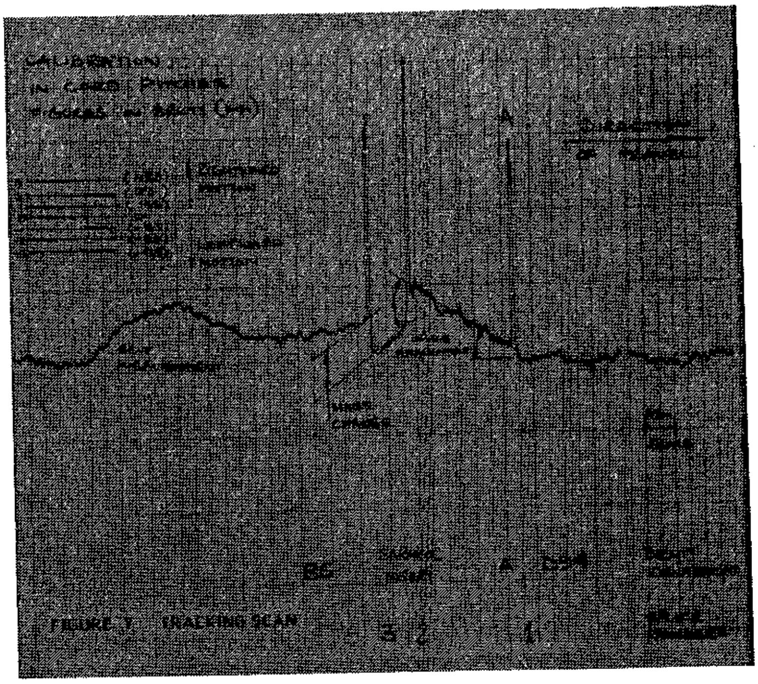


FIGURE 7 TRACKING SCAN

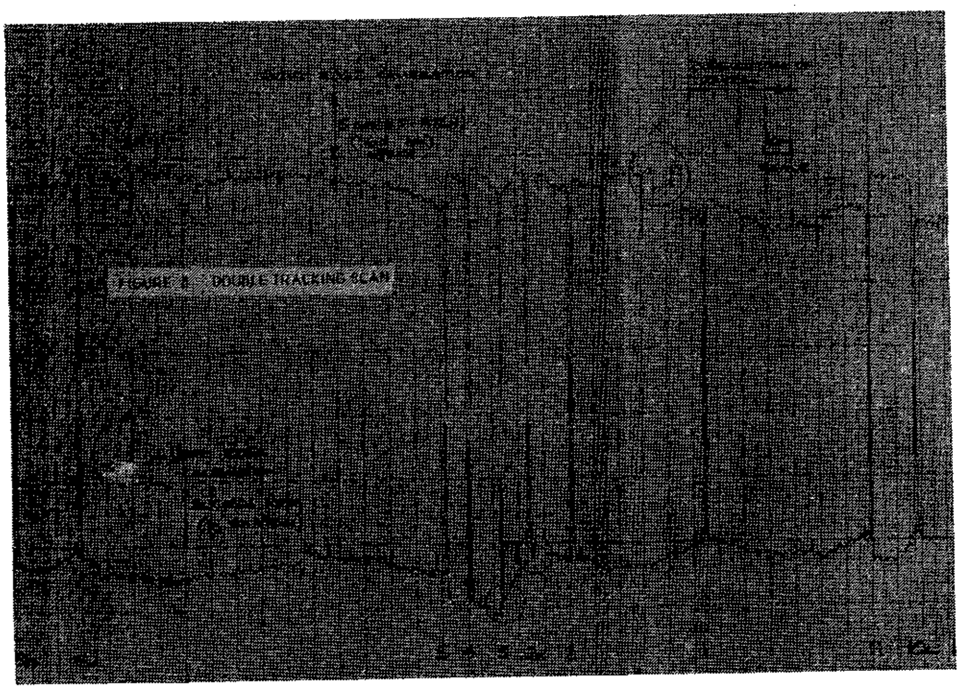


FIGURE 8 DOUBLE TRACKING SCAN

4.0 EXTENSION TO THE SCANNING SYSTEM

Two major factors became apparent after local scanning started.

(a) Much belt deterioration - particularly visible deterioration - is the result of tracking problems.

(b) Breaks have a vital influence on carcass life.

4.1 Tracking

This technique uses the property that a fixed scanner on the side of the belt detecting mass will record the wander of a belt as it passes the scanning point (3). Independantly from structure, idler or pulley problems. Fig 7 shows such a trace. Note that the splices are self marking by their overlap masses.

The figure clearly shows the distinction between splices where the belt direction is similar at splice entry and exit marked "mass change" and those where an "alignment change" has occurred. The tracking error is also measured. The area marked "Belt Misalignment" reflects the ability to identify belt sections where tracking problems are built-in. This one was a section of ripped belt that had been repaired by re-joining the two sections and revulcanising. The mine was thus able to identify some repaired sections which were satisfactory and others where alignment would be a long term problem, and replacement should be budgetted for.

There are two limitations to the process. Firstly, severe edge damage, in which case dual tracking scanning is used. Here each edge is scanned and

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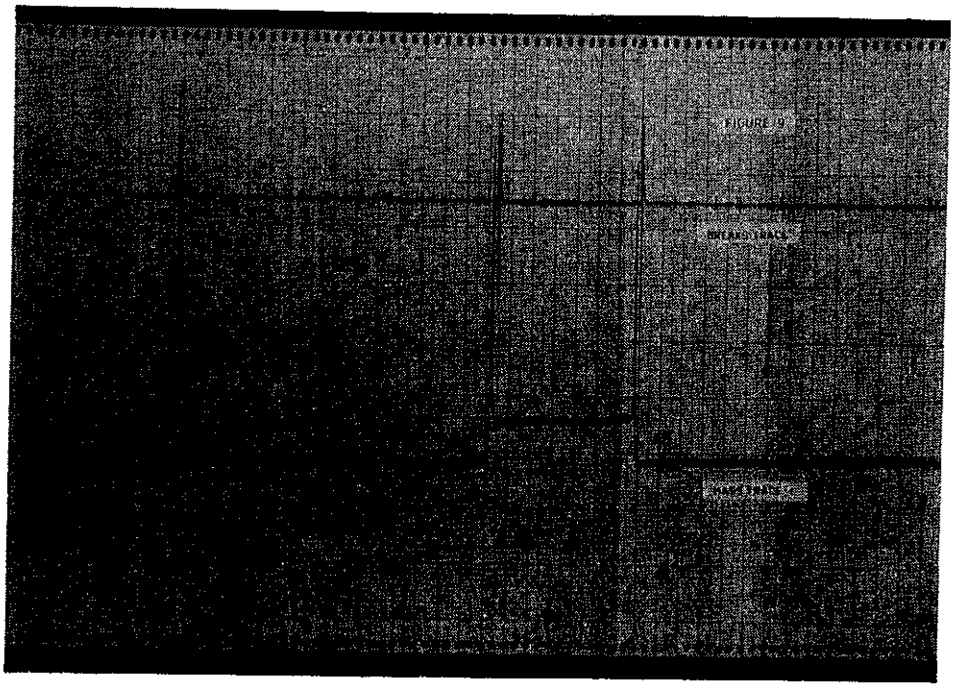
the results synchronised back-to-back. Fig 8 shows such a trace. In this scan left and right edge (e.g. 'X') also central damage can be identified clearly and net belt movements such as those around splices 2a and 3 are recorded.

Secondly, the state of load of the belt. This is normally overcome by scanning on the return strand close to the take-up. Where tension is lowest and most constant. If also means that load can be carried throughout scanning, at full fly speed. Where this is not possible the belt is scanned unladen for this part of the process.

4.2 Breaks

A break is defined as a point where cords are severed without loss of steel mass. Such points require a distinct technique for identification, they may or may not be visible to the eye or to X-ray. The upper trace in Figure 1 is a syncronised break trace in which it can be seen that broken cord ends appear at some, but not all, mass losses. Figure 9 shows the opposite. The belt section between splices 2 and 3 has a problem found to be exposure of a single cord displaced from the cord plane and being damaged where it is on the belt surface.

To illustrate the sensitivity of the method a case history is appropriate. A long overland belt in the Transvaal has a history of sudden failure without apparent cause. Regular scanning on this belt found no corrosion and few detectable splice problems. Breaks scanning showed some breaks which were located and visually identified. Fig 10 shows a diagram of the visible damage at one of these points, marked '3' on the trace in Fig 11 which



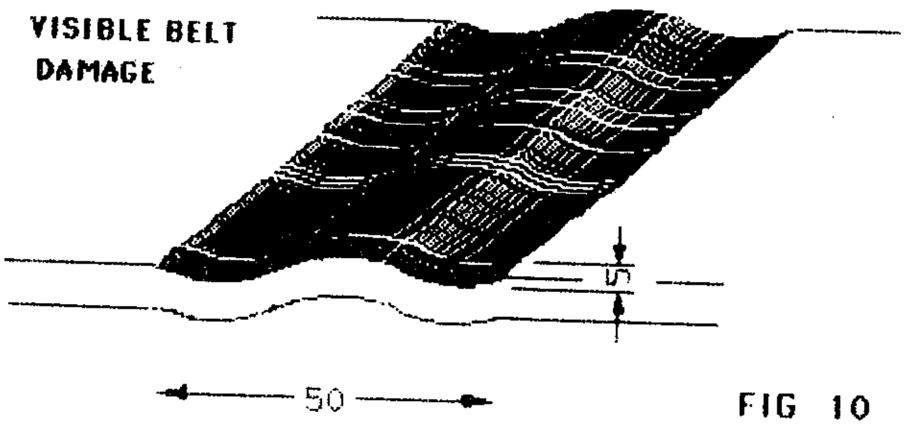


FIG 10

also shows the actual damage as 'X' rayed. The two cords circled show crushing and all the cords across the belt have some permanent set. The suspected cause is an earlier failure during which the belt became entangled between the drive and snub pulleys, Fig 12, and was tightly bent. Future scanning of this feature will ensure that any growth of the breaks can be monitored and action taken when indicated. This is one of three such points on the belt.

The major limitation to the process is lack of calibration. A widely separated small break can appear similar on the trace to a large break with little or no gap. Visual inspection of each significant signal is required to offset this. Including, if indicated, cover stripping as part of the repair process to uncover the whole break. In this way non-visible breaks up to 9 cords have been discovered.

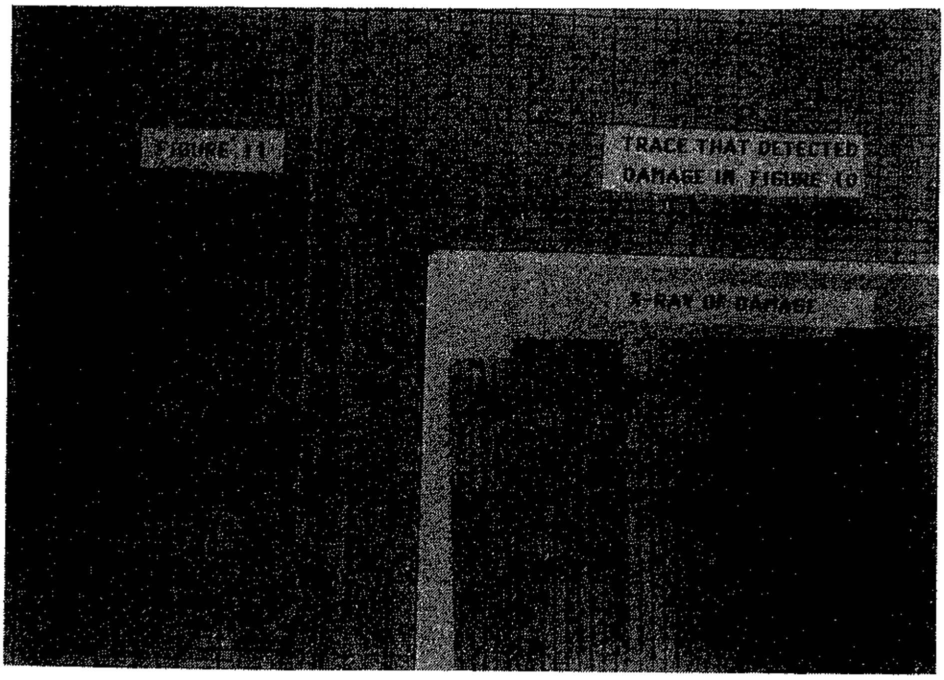
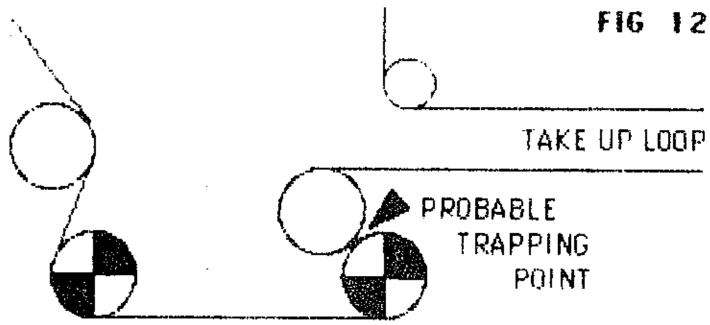


FIG 12



CONVEYOR DRIVE IN WHICH BELT WAS FOLDED

5.0 MONITORING IN OPERATION

There are a number of distinct patterns emerging in successful local use of the process. These fall into 3 categories.

5.1 Long term monitoring based maintenance programmes
5.2 Short term information collection for decisions
5.3 Non-destructive testing of new belts as a manufacturing check

5.1 Several major users are concerned regarding the life of their belts. These deteriorate typically due to rips and slow attrition of the edges. Long loose edge cords and cord ends generated at central breaks have become snagged and caused belt ripping and failure. The aim in such cases is to identify each leading edge cord end, also individual breaks, then to apply an effective, permanent, repair. Measurement is at around the 1% damage level.

There is a major challenge for the belt repair industry here in the supply of effective long term site repair methods comparable to factory repairs for edges and minor breaks.

Fig 13 shows an Australian belt scanned at 12 month intervals after repair in this way and recording corrosion growth, repairs and stable edge losses.

Where this is being done the belt condition has consistantly improved rather than deteriorated. In the long term the ageing process will be controlled and selective replacement of belt sections can be practiced rather than wholesale belt scrapping. Ideally, after the full expected life is achieved.

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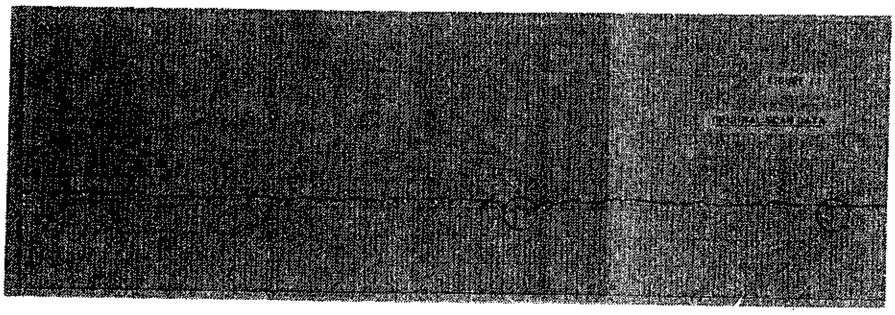

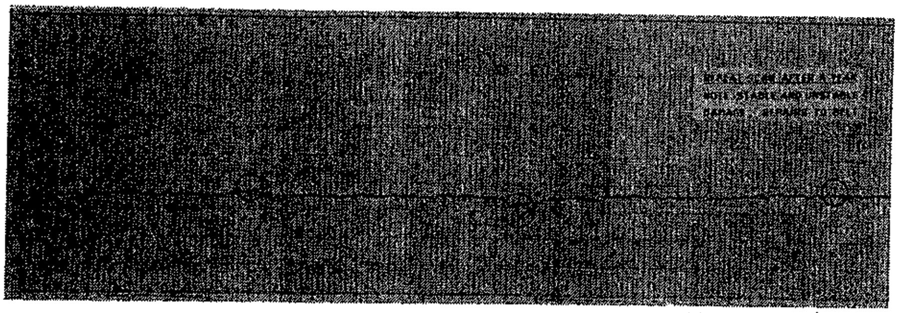

5.2 Where the condition of a belt is unknown or a major decision has to be taken as for instance the replacement or refurbishment of a belt during a plant outage, scanning has been performed.

To get the best from such a scan the maximum information is required and the co-operation of the repair or refurbishment agency is needed early in the project. The exercise may result in a projected useful life, a derating recommendation or a repair or replacement recommendation by sections or wholesale. The best life extension directly achieved in this way is 3 years in Australia and 18 months locally.

5.3 As noted earlier belts on commissioning are far from defect free, although the requirements of SABS standard (4) may have been fully met. The record for a new mine with four steelcord belts commissioned for less than 20 months included tracking problems, cover variations, unidentified steel loss, uneven cover wear and inconsistent splice construction. A scanning programme has been instituted to control long term damage based on these "signature" scans.

One manufacturer has instituted a scanning programme to investigate cord and cover anomalies at a detail level in a recently supplied belt. This is chiefly notable for the fine detail that can be obtained over a period of time with little or no interference to the users operations.

6.0 BELT LIFE

Apart from reduction in breakdowns, the chief gain to be had by monitoring steelcord belts is life extension. It is not unreasonable when installing a shaft or overland belt to expect between 10 and 15 years service, except in the case of fire resistant belts. It is quite rare to achieve this. The oldest steelcord belt in the country to our knowledge, has been carrying iron ore reliably for 10 years. Whilst a number of belts in less arduous applications have been replaced after only a few years. The oldest Australian steelcord belt was replaced last year after 20 years service. Our local situation can and should be improved.

The major factors governing belt life are:

6.1 Cover wear
6.2 Carcass damage
6.3 Cover hardness

The ideal lifespan will be obtained when a natural rubber belt is evenly worn on both sides to the point where rip-risk is intolerable or for fire resistant belting when the increasing hardness causes the same effect.

6.1 Cover Wear

Assuming that the carcass is in adequate condition a simple cover thickness measurement such as that in Fig 6 can be matched to tonnage records and thus provide an estimate of cover wear per thousand tons. In fact this belt, which is in a heavily worked incline, has such slow wear rates that several years must elapse before it can be measured, this we find typical of black coal installations.

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By contrast a well worn belt such as shown in Fig 14 had lost approximately 3 to 3,5 mm of top cover in 7 years of operation. This is an iron ore reclaim belt due for replacement shortly.

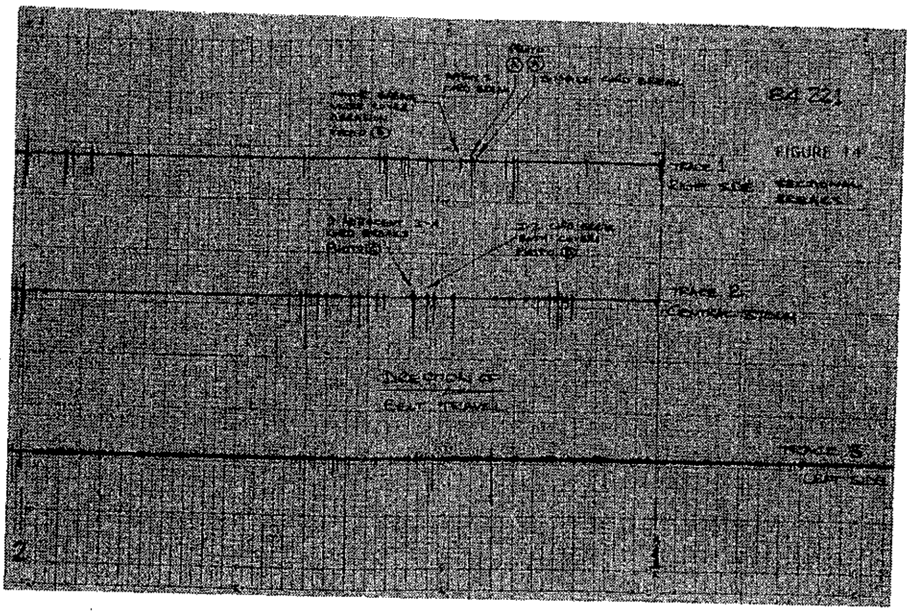
Referring to Fig 6 a feature such as the central thin area can be identified as to length by relating lateral and longitudinal scans. In this case the amount of belt involved was less than 50m, therefore the thin region was discounted from life calculations as it may readily be replaced, having been identified. This situation must be treated with care since such regions often indicate abnormal wear rates which should be dealt with.

6.2 Carcass Damage

Given the comments on wear rate above, the carcass can be expected to determine the life of the majority of steelcord belts. Rip incidence is a major factor in carcass loss. Beyond supporting a policy of good housekeeping that topic is outside the scope of this paper.

A case study will give an insight into how other factors in carcass life can be estimated using monitoring techniques. Fig 14 shows a sectional break scan for the subject belt. The following points are also relevant.

(a) No tonnage figure were available for the belt
(b) Tonnage carried and damage creating conditions were estimated to be stable.
(c) No corrosion was detectable in the carcass



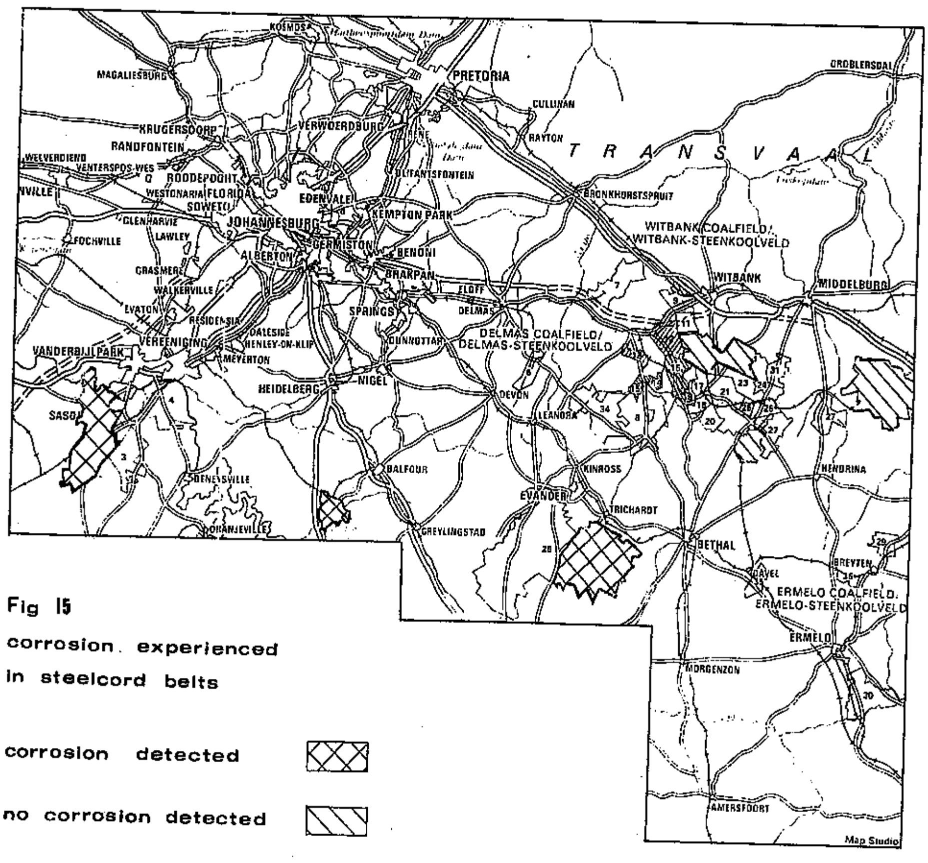


Fig 15

corrosion. experienced
in steelcord belts

corrosion detected

no corrosion detected

(d) Edge losses of only up to two cords were detected.

(e) A five year period only was to be considered

Breaks were visually identified and sized. The largest breaks were found to be 4 to 5 cords in extent. 220 Breaks were recorded in this 1075 m belt. The scan indicates that the breaks are evenly spread through the belt, also that breaks often occur in pairs and thus make only a single contribution to loss of strength. At several points breaks are seen to occur in different portions of the width of the belt simultaneously. The maximum extent to which thus occurs is 6 to 8 cords equivalent (6 to 8% of this 100 cord belt). The chances are good that this will also occur in the next 5 years of operation giving a probable net loss of 12 to 16 cords (12 to 15%). It is not probable that this will be exceeded - although it is possible.

It was recommended that the carcass life could be extended five years if current breaks damage was repaired at the points indicated on the scan, by laid-in-steel methods. An alternative would be to de-rate the belt a specified amount to allow for the deterioration. In either event the belt would be comparable to a new belt of the relevant rating.

Had corrosion existed "lifing" becomes more uncertain due to the inconsistent rate of corrosion. However, since corroded areas have a high repair success rate and can always be spliced-out they are less of a problem than large numbers of small breaks, provided the extent and location of corrosion can be measured.

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6.3 Cover Hardness

In FRAS and other belts cover cracking related to hardness is a problem about which much needs to be learnt. No precise life indications can be given but the following notes may be helpful.

Hardness is routinely recorded during scanning. It is therefore possible to confirm that the reported annual increase in hardness (2) for FRAS belting of 1,5 RHD Shore 'A' is reproduced in local belts. A higher rate of increase has been measured typically, but the sample is too small to be conclusive. Five such belts are regularly scanned with hardnesses over 80 RHD. No carcass failure in these belts has yet been reported, cracks are present together with delamination.

Hardness of up to 75 RHD in natural rubber belts has been measured, cracking is also present in these belts.

6.4 Belt Stock Levels

It has been found in practice that the predictive aspects of monitoring allow radical reductions in spare belt stock levels. This has been the foundation for a number of belt scanning programmes.

7.0 CONCLUSION

The process of electrical monitoring together with rip control and visual inspection can provide the steelcord belt operator with all the information be requires to;

7.1 Continuously repair and maintain the belt and hence preserve the belt carcass

7.2 Predict well in advance the life expectancy of each individual section of the belt

7.3 Plan and budget replacement of a belt. Section by section or wholesale, in order to reduce stock levels

7.4 Extend net belt life by selective replacement of part sections to cure problems such as local cover thickness, corrosion and edge damage

7.5 Where a new belt is fitted or commissioned, monitoring provides non-destructive testing facilities capable of permanently recording the actual status of the belt on hand-over. Thus also providing a "signature" scan for future monitoring.

The parameters measured have a slow rate of change in general and scanning at 6 to 24 month intervals has been found appropriate.

It is currently extremely rare for a belt to be withdrawn from service due to cover wear. It is an aim of scanning programmes to preserve the belt carcass so that this becomes the norm. This implies a considerable increase in average belt life.

Some external factors should also be mentioned which affect belt life.

7.6 Storage of spare belts in unsuitable conditions.

7.7 Ready availability of good repair procedures for minor damage

7.8 Consistent standards and adequate supervision of splicing

7.9 An adequate - meaningfull - standard for belt manufacture

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This last item reflects the situation in which the current SABS standard is based on short test samples of parameters which vary widely over less than a metre. Whilst items such as matching number of cords in a given rating of belt for splice consistency are not standardised. It is suggested that the time to review the standard, in the light of available continuous measurement techniques has come. That these technique have come of age is independantly confirmed (5)

In the long term a databank will be built-up from scanning informationwhich is aimed at assisting industry decision making. A simple example of how this can work is Fig 15 showing the areas where corrosion in steelcord belts is a problem. Over the years this data will be extended and refined, to be made available for selection between steelcord, Kevlar and Carbon Fibre belting as these options become standard.

Similarly, user mines do have difficulty with consistent stock and belt replacement policy. Information is available already to help improve targetting of realistic expectations from steelcord belting. This will be enlarged continuously. For example, the two horizontally curved belts scanned so far show no special defect characteristics, as they age this will be monitored.

Measurement, as opposed to observation is able to collect and compare data quickly allowing early cures for built-in problems wether of belt or conveyor.

Finally, we ask is it reasonable that a low cost item in a new installation such as a terminal pulley should be built like a pressure vessel with all that implies in quality assurance, yet the belt running over it is subjected to little or no independant carcass quality checking.

ACKNOWLEDGEMENTS

Our appreciation goes to the mines who have shown such faith in us at this early stage and to the management of Bosworth Holdings who know a good idea when they see one.

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