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BELTCON 4

Modern Concepts in Belt Rip Detection for Steel-Cord Reinforced Conveyor Belts

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1. Summary

Steel-cord reinforced conveyor belting evolved out of need in the U.S.A. in the late 1930's for a belt capable of transmitting much higher tensions than those then available. This resulted in the first successful belt being put into use in 1942. We have come a long way since then. However, at the same time, the technical and economic consequences of belt damage have become more serious, resulting in the need for a reliable rip detection system. This paper briefly discusses various methods, spending additional time on the Electrical Circuit Loop Inclusion system.

2. Introduction

2.1 History

Transporting of bulk materials by conveyor belts dates back to approximately 1795; most of these early installations handled grain over relatively short distances.

The first conveyor belt systems were very primitive and consisted of leather, canvas, or rubber belt travelling over a flat or troughed wooden bed. This type of system was not an unqualified success but did provide incentive for engineers to consider conveyors as a rapid, economical, and safe method of moving large volumes of bulk materials from one location to another.

During the 1920's, the Colonial Dock installation of the H.C.Frick Company in the U.S.A. showed what belt conveyors could do in long distance hauling. This installation was underground and handled run of mine coal over some 8 kM. The conveyor belt consisted of multiple plies of cotton duck and natural rubber covers, which were the only materials used to manufacture belting at that time.

2.2 Evolution Of The Steel-Cord Reinforced Conveyor Belt

The increasing need in the late 1930's for conveyors capable of handling larger tonnages over longer distances and up steeper grades, prompted Goodyear to revive the idea of using steel cords for the tension member in order to provide a belt which would exceed the tension ranges possible with the cotton textile cords. This revival was made possible by the development of small highly flexible steel cords.

The result was the world's first steel-cord reinforced conveyor belt, produced by Goodyear. It had an operating tension range of 160 kN/m of width and was installed in 1942 at Oliver Iron Mining Company's Morris Mine. This belt proved to be so successful in accomplishing the task for which it was designed that Oliver purchased two more belts; one for the Gross Marble Mine with an operating tension equivalent to a Class ST1000, installed in 1945, and the other for the Hull-Nelson Mine of Class ST1400, installed in 1947.

The success of these belts created wide interest with everyone who was concerned with handling large quantities of bulk material and resulted in two more being installed in 1948.

In 1957, the strongest belt ever built up until that time was installed by Goodyear, in Consolidation Coal Company's Loveridge Mine. This 1200mm wide Hercules was designed to handle 1500 tons per hour on a 915 meter slope with a lift of 252 meters. Maximum tension was approximately 408 kN/m, and was powered by two 600 kW motors. It remained in service for an incredible 22 years.

2.3. Current Steel-Cord Design

The introduction by Goodyear in 1942 of steel-cord reinforced conveyor belting with its high strength, negligible stretch, almost 100 per cent splicing efficiency, greater flexibility and longer life has allowed for exceptional efficiency gains in long hauls, increased incline and curving capability, carrying capacity, impact resistance, non-proliferation of drives and take-ups, factor of safety consideration, reduced down time, pulley sizes, etc.etc. Its use has developed extensively worldwide over the last 45 years, with special emphasis in Southern Africa since 1975.

The huge increase and projected trends in the cost of energy over the last decade and a half has had the effect of:

- prompting an unprecedented surge of projects to exploit world coal reserves; to allow for efficient handling in the international trading of that coal; to accelerate the development of oil from coal technology; and to exploit the world's huge reserves of tar sands and oil shales and

- highlighting the energy conservation and cost gains that can be achieved by all long haul bulk handling operators in moving from truck or rail transport to belt conveying.

The next decade will see a further growth in the use of steel-cord reinforced conveyor belting.

We are now in a new cycle of increased tension requirements for conveyor belting, which can only be satisfied with high strength steel-cord or the relatively new and extremely expensive aramid fibre reinforcing.

This cycle has brought us into operating tension levels in the range of 1 000 kN/m of width, and more, as opposed to the 160 kN/m required of the original steel-cord belts. Obviously, no textile constructions of conveyor belting are available at or near this level of operating tension.

3. The Major Problem Faced By Users Of Steel-Cord Reinforced Conveyor Belting

We have covered the evolution of steel-cord reinforced belting, and I'm sure that you will all agree that the special properties of this construction makes for long belt service life. However, at the same time, the technical and economic consequences of belt damage have become more serious.

Users of steel-cord belting have usually suffered, and certainly fear belt rip. Such is the power of modern drives that unless an intrusion is seen, and, the observer speedily initiates the conveyor stop, long lengths or at the worst the complete belt can be cut, like a hot knife through butter, in very little time.

At best the conveyor will be down for a long period of time and tens of thousands of Rands will be lost in the cost of inserts and repair. At worst, hundreds of thousands of Rands can be lost in complete belt replacement and/or several days or weeks operational interruption. It is this potential for the complete loss of a conveying line that has led, I believe, to the costly practice of duplicating systems at some of our major power generating facilities.

The potential causes of damage include:

- All operating contingencies likely to induce longitudinal tearing. A lump of material conveyed, or foreign body may become wedged in a stationary part of the conveyor and rub against the belt. If this material, or foreign body, is of such shape and hardness and is wedged in such a position as to penetrate deeply into the belt thickness, puncturing and tearing may result, possibly over a considerable length.

- In this respect, it should be noted that once puncturing has commenced, the only satisfactory outcome that can really be hoped for is ejection of the foreign body.

4. Is There A Solution?

YES!. A number of systems have been designed to protect conveyor belts from longitudinal rips and so avoid the costs associated with downtime and belt repair; and as more long-haul, heavy-duty conveyor systems have been placed in service, belt manufacturers in particular, have addressed the problem of designing a reliable, durable rip detection system.

The four most common routes followed have been :

(1) Mechanically Operated Devices

(2) Ultrasonics.

(3) Transverse Reinforcing Rip-Stops.

(4) Electrical Circuit Loop Inclusion.

These will be examined in the order of their effectiveness.

4.1 Mechanicallly Operated Devices

These can best be described as mechanical in operation by the method used to activate the stop switch. Fig 4.1 shows a typical device. There are many variations on the same theme, and are as numerous as there are designers and draughtsmen.

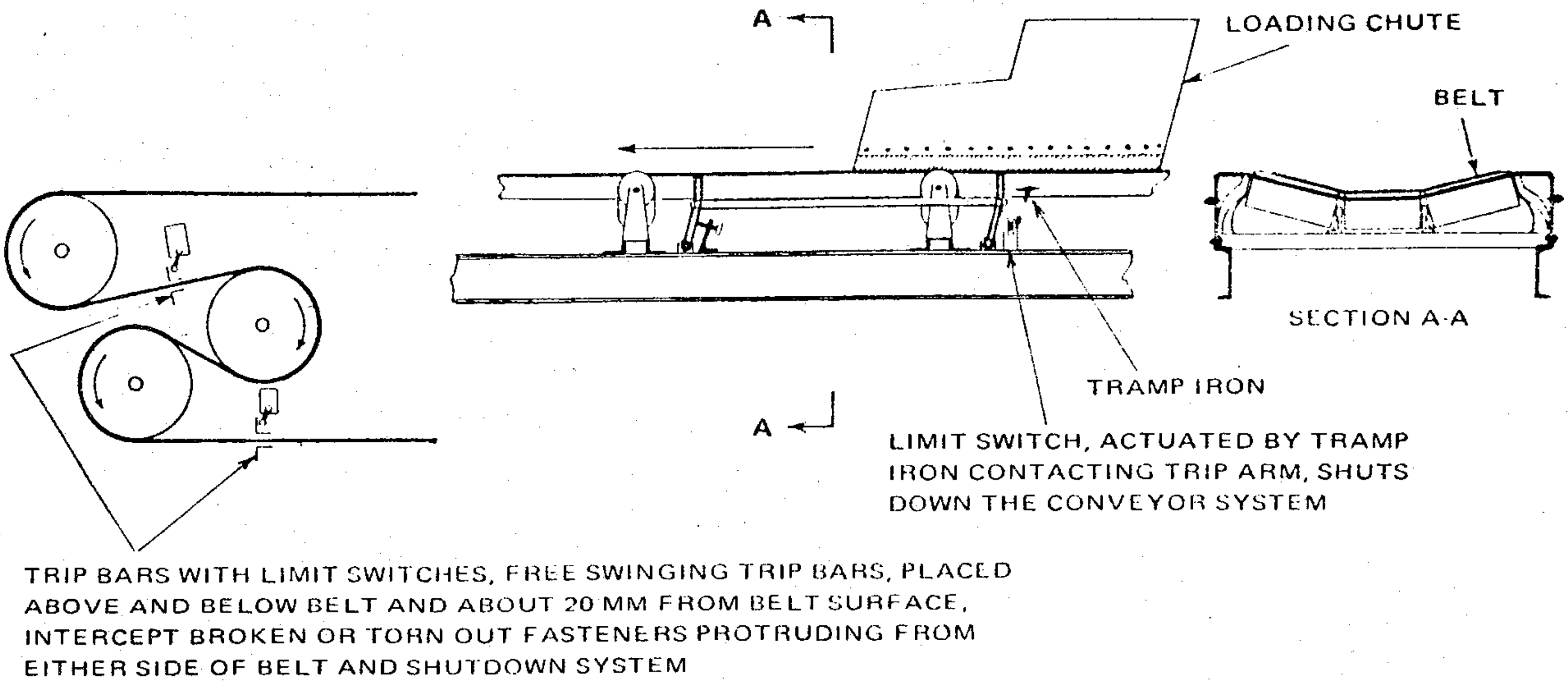

Figure 4.1 – Rip Limiting Safety Devices

Some of these devices undoubtedly work, but how reliable are they? The very nature of the operating environment of most conveyors, preclude the chances of a high success rate.

4.2 Ultrasonics

Typically, one of the biggest problems with ultrasonics is coupling the high frequency sound waves (ultrasonic sound) to the test material. Substances such as air, dust, loose material, soft material, etc. won't conduct these sound waves. In one system studied, attempts have been made to try and overcome this major drawback in a couple of ways. The first, a water coupled transducer, is probably a good means for coupling to a moving belt, but it is not conceivable to think that this type of transducer would be useable anywhere. The second solution, a special fluid membrane wheel, will also do the job but has many inherent problems. From my own company's experiences with belt followers, we feel that such an arrangement would be totally unsatisfactory from a maintenance standpoint. Dust and dirt build-up on the belt and wheel could easily prevent ultrasonic sound from being transferred into or out of the belt. Any mechanical element has moving parts, and moving parts (by definition) wear out and are, therefore, a maintenance problem!

The difficulty of transmitting ultrasonic waves through materials can be seen from the fact that a belt that is slit but not separated, will, in such a system, cause a loss of transfer of ultrasonic energy across the belt. It is questionable, however, whether water in the slit would transfer the energy as if there were no slit, thus making the system totally ineffective for many belt rips.

It would also seem that general belt deterioration (concerning ultrasonic energy conduction but not affecting belt performance) could easily mask such a belt slit since the signal would be down in the the "noise" threshold established by belt deterioration or ultrasonic coupling problems.

Several major points to consider are:

(a) Transducer tracking on most belts would be a problem.

(b) Keeping the belt and transducers clean enough to maintain ultrasonic coupling and prevent false shutdowns would be a serious problem in most conveyor environments.

(c) The transducer must be extremely well protected against mechanical abuse.

(d) Mechanical problems with seals and rotating parts in the transducers will pose a serious maintenance problem at any installation.

(e) The ultrasonic power necessary would probably be appreciable, thus the "control unit" would have to be near the transducers. This is not always possible or desirable.

Ultrasonics may be the final solution, however, at the time of preparation of this paper, the author was not aware of any system that was operating satisfactorily, employing the medium of ultrasonics.

4.3 Transverse Rip-Stop

Transverse reinforcement increases the belts resistance to puncturing and tearing, however, the degree of protection afforded by this method is debatable. In this respect, it should be noted that once puncturing has commenced, the only satisfactory outcome that can be hoped for is ejection of the foreign body.

Experience shows that within conceivable weft breaking strength limits, resistance to longitudinal ripping is approximately 25 000 Newtons.

For a speed of 3,0 meters per second, the power developed by belt resistance is then about:

25 000 * 3,0 / 1 000 = 75 killowatts

To take the example of a conveyor of 1 800 meters center distance with a lift of 45 meters, and a capacity of 1 100 tonnes per hour on a 1 000 mm wide belt, total installed power is 440 killowatts. This places in perspective the reactive power developed by weft tearing, as calculated above.

Whatever the nature of the weft, once a sharp body has penetrated the belt and attained a position likely to cause longitudinal tearing, weft resistance to propagation of the cut is generally slight compared with the conveyor's driving power. On large conveyors, where variations in loading rate must be allowed for, such input power fluctuations cannot be harnessed so as to cause electrical trip-out, and stop the conveyor.

As previously stated, transverse reinforcement does afford a small degree of resistance to puncturing and tearing, however, the degree of protection afforded by this method has its limitations.

NOTE! If this method is chosen, then it is recommended that the reinforcement be continuous, and not in short lengths at regular intervals, as advocated by some users.

4.4 Electrical Circuit Loop Inclusion

This method of rip detection can be offered by some belt manufacturers, in most cases sourced from a third party. Some are extremely sophisticated, incorporating microprocessors etc.. Others have been kept relatively simple whilst still providing the same degree of protection.

How do such systems help to prevent major belt damage?

Figure 4-2 shows the basic components of such a system and their relative positions in an installation.

Sensors (A) are relatively small figure 8 conductive loops which are built into the bottom cover of the belt at regular intervals extending across the width of the belt from edge to edge.

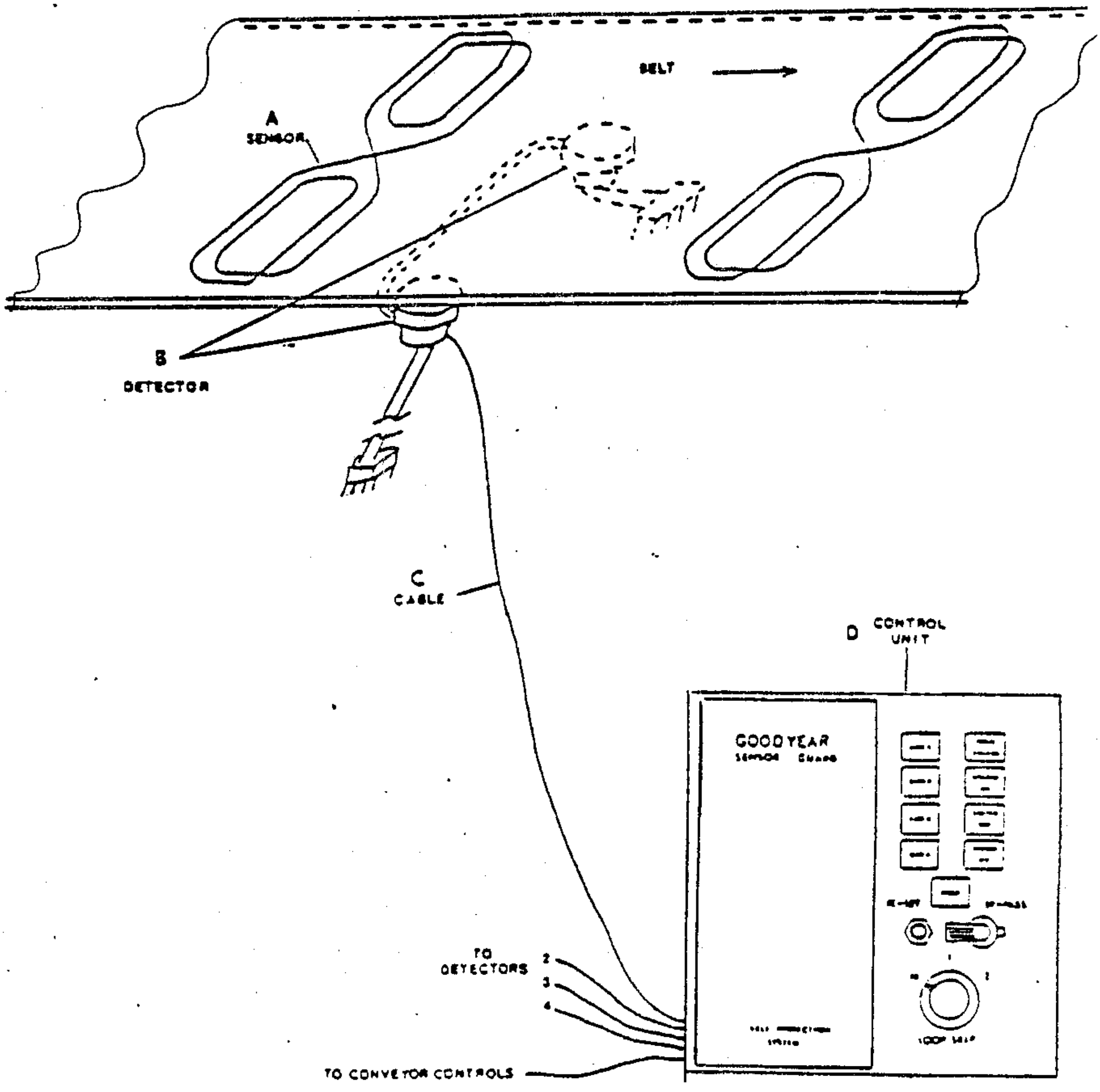

FIG.4-2 SENSOR GUARD System Diagram

A pair of detector heads (B) is mounted on the conveyor structure immediately following the high risk damage area. These heads are positioned about 100 mm below the belt's non-load carrying surface and are aligned with the sensor's loops at each edge. Cable (C) connects the detector to the control unit (D) which is mounted at some convenient location.

As a good sensor passes over the detector, an output pulse is generated. A continuous series of good sensors passing over a detector causes a continuous series of detector pulses. Each detector pulse resets a timer in the control unit. If a sensor is severed (open circuited), due to belt damage, the timer will not be reset, will time out, and the control unit will issue a belt stop command immediately to the conveyor controls. Similarly, when belt slippage or excessive lateral movement occur, failure of a sensor loop to pass over a detector within a prescribed time interval will cause an automatic belt shutdown.

The loop-skip function lengthens the timer's period, thus allowing the belt to continue to be protected in operation even if an occasional sensor becomes damaged. Thus sensor replacement can be carried out during scheduled maintenance shutdowns.

Figure 4-3 shows an optional site detector arrangement which automatically selects good belt sensors while ignoring those sensors which are missing or have been damaged for reasons other than belt slitting, or lengthy belt sections without sensor loops.

This look-ahead arrangement provides a high degree of belt protection for the high risk areas because its timers are based on the time required for any single belt sensor to travel between two detectors rather than the time between adjacent belt sensors (as in the single detector arrangement discussed previously.)

As illustrated in Figure 4.3, two identical detectors and a look-ahead coupler generate the appropriate signals for the control unit timers. One detector (det."A","look-ahead") is placed immediately ahead of the high risk area and a second detector (det."B","normal") is located a short distance (to let the load settle) after this area. (The distance between "A" and "B" must be less than 85 per cent of the sensor spacing).

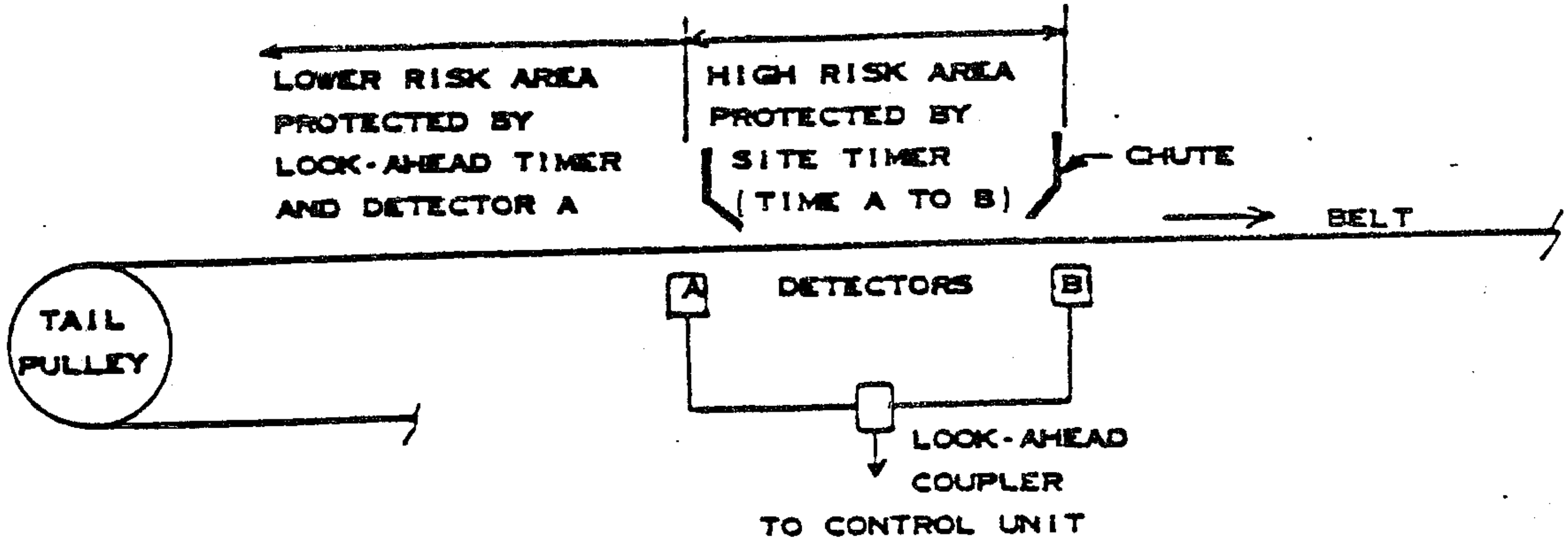

FIG. 4.3 LOOK-AHEAD SITE DETECTOR ARRANGEMENT

When a good sensor is detected by "A", a timer (site timer) is started. If the sensor travels through the area undamaged (no belt rip), "B" detects it and resets the timer thus allowing the belt to continue running. On the other hand, if the belt starts to rip between "A" and "B" the sensor will be severed and "B" will not detect it. Thus the timer will not be reset, will time out, and the control unit will issue a belt stop command.

A second (look-ahead) timer is associated with detector "A" such that "A" and this look-ahead timer act in the same manner as the single site detector arrangement previously discussed. The look-ahead timer is set so that a good sensor must arrive at "A" within a prescribed time interval (usually 1 or 2 belt sensor time periods) after the last good sensor passed "A", or the belt will be stopped. Thus detector "A" looks ahead, or up the belt against the direction of travel to limit rips which may initiate in the lower risk area of the conveyor. This timer is not affected by the loop-skip control.

The look-ahead site protection system is capable of providing a wide variety of site protection arrangements. An example being a loading area that is longer than 85 per cent of sensor to sensor distance. In such a situation the detectors could be "chained" together and so provide the protection necessary.

5. What Features To Look For In A System

5.1 Reliability:

Excellent immunity to vibration, electrostatic discharge, and electromagnetic interference. Detectors should be capable of working in wet, icy, and dirty conditions, and at temperatures from -40 to 100 degrees C.

5.2 Fail Safe Indication:*

A warning should be provided and the conveyor stopped if belt damage occurs, or in some cases, is impending. If the system itself fails, a warning is provided. At the customers option, the system can be wired to either stop the belt or keep the belt running for systems failure. Thus conveyor operation need not be interrupted by a system failure or ensuing repairs.

* Although absolute fail safety is unattainable, it is felt that such a system should attain a level beyond normal expectations for fail safe designation.

5.3 Minimal Maintenance:

Such a system should not only be rugged, but should be capable of detecting and indicating its own malfunction without affecting conveyor operation, no maintenance should be required. There should be no moving parts such as brushes or commutators. Detectors should be potted and fully encapsulated. Once installed and adjusted no reprogramming or sensitivity adjustments should be necessary. The circuitry should be straightforward and be easily understood by electronics maintenance personnel.

5.4 Remote Stop/Start:

It should allow normal start/stop operations, after initial startup, by automatically freezing the systems status while the conveyor is stopped. Since "external" stops are thus ignored, control units may be "chained" in any stop circuit thereby allowing a more cost effective installation.

5.5 Optional Look-Ahead Site Detection:

Automatically selects only good sensors, ignoring those missing or damaged. Thus belt protection can be made independent of sensor interval

5.6 Automatic Creep Mode:

Will automatically accommodate a second, lower (creep) speed.

5.7 Loop Skip:

Allows continued protection even with some damaged or erratic sensors.

5.8 No Conveyor Modification:

Simple to fabricate detector mounts and non-critical detector to belt spacing (maximum 250 mm nominal 100 mm) to facilitate easy detector installation.

5.9 Numerous Control And Indicator Functions:

Status of belt and system clearly indicated. Relay contacts should be provided for conveyor and system status indicators.

5.10 Field Replacement Of Belt Sensors:

Sensors should be capable of being retrofitted in the field with normal belt vulcanising equipment.

5.11 Simple Installation Or Expansion:

It should have virtually unlimited detector to control unit separation and multiple sites per control unit allowing economical system installation or expansion.

5.12 Modular Construction:

The system should be divided into several major functional units. Each unit being easily separated from the rest, thus facilitating efficient and economical installation and maintenance.

5.13 Universal Application:

The system should be designed to provide maximum belt protection for virtually every type of damage risk area associated with conveyor belts. Input and output signals should readily interface with all types of electrical and electronic conveyor control systems.

6. Planning For Belt Rips

With a functional, reliable rip detector now available, conveyor operators can minimize their dependence on inventory stock for replacement belts.

Rip detectors are not practical for every conveyor application. Market studies suggest that rip detection becomes appealing when replacement of belts is not practical from the point of view of operating efficiency and/or when replacement belts are not readily available. Steel-cord belting definitely falls into this category. Such belts, being custom made items, are not generally a stock item. As the steel cords used in their manufacture have to be imported into South Africa, replacement of these belts requires a long delivery time and could result in excessive downtime.

The cost of maintaining belting replacement stock can be prohibitive. At one mining operation in the U.S.A., a 700 meter long belt in use on a slope system is valued at $125 000, and the belt is considered to be so important to the operation that prior to the installation of a belt rip detector, a full spare was kept on hand at all times. Installation of a rip detector at each end of of the conveyor enabled the operator to reduce his stock holding to 170 meters of replacement belting.

Normally, the major economic consideration influencing a decision to install a rip detector is the effect of downtime on a facilities operations. The cost of downtime varies widely from one operation to the next, and some operations are better suited to deal with a disrupted production schedule that accompanies the loss of a belt. If scheduling and delivery are crucial, the use of rip detectors provides an alternative to time lost to belt replacement and repair.

Belt rips occur more frequently than most belt operators realize, or are willing to admit. Of 14 installations studied by a major US belting manufacturer over a one-year period, three experienced belt-rip incidents, a rip rate of more than 20 per cent.

Studies carried out in the U.S.A. show that approximately 80 per cent of rips in high-value, heavy-duty belts occur at or near the loading point. Another 15 per cent occur near the discharge point. If rip detectors are to be used, the best protection for the conveyor system is afforded by placing a detector at each end of the system, thus protecting the belt in 95 per cent of potential rip situations.

7. Case Histories Of "Sensor Guard"[R]

The following represent some case histories of where the Goodyear "Sensor Guard" system, which is of the "Electrical Loop Inclusion" type has been successful in limiting the extent of rips.

The major drawback perceived with this type of system has been the reliability of the sensors themselves. This criticism could have been valid some 10 years ago but is not the case today. The sensor construction now used, has been in use for 7 years in hard rock mining applications, and has proved to be extremely reliable.

During a 10-week period in 1986, operators of three separate facilities estimate saving a minimum of $2,5 million just because they had installed Goodyear conveyor belting with this unique rip-detection system.

7.1 Iron Ore Terminal, U.S.A.

When the main center take-up pulley broke on the 670 metre primary conveyor at LTV Steel's Lorain, Ohio, iron ore pellet terminal, Sensor Guard shut the system down when the rip reached the first sensor, limiting the damage to just 23 metres.

Without Sensor Guard, LTV officials estimated it would have cost about $150 000 for a new belt and about $45 000 a day for downtime.

7.2 Copper Mine, U.S.A.

In early December, a large arrowhead-shaped piece of copper ore tore a section of a new 1 006 metre Goodyear steel cord belt at Cyprus Mineral's Sierrita Mine, near Sahuarita, Arizona. But the unit automatically shut down when the rip reached the first sensor, damaging just 61 metres of belting, and temporary metal rip plates were installed immediately.

There was virtually no downtime, and the ripped section was replaced during the next scheduled shutdown. Officials estimated that replacement cost of the belt alone would have been over $250 000, and subsequent cost of downtime, labour and loss of production could have accumulated at a rate of over $384 000 a day for as many as 14 days.

7.3 Copper Mine, Chile.

At the world's largest copper mine near Antefegasto, Chile, a steel plate jammed between the cords of a 5 364 metre section of Goodyear Flexsteel belting carrying copper ore from the crusher out of Codelco's huge Chuquicamata pit.

Within a matter of seconds, the belt automatically shut down, limiting damage to a small 40 metre section.

According to officials of the state-owned mine, if the Goodyear Sensor Guard equipped belting had not been installed, it would have cost an estimated $2 million to replace the belt; downtime would have been 44 days costing over 8 400 man hours; and "hundreds of thousands of dollars due to the loss of moving material" would have resulted.

On-site maintenance personnel said, "The Goodyear Sensor Guard operated as expected, detecting the problem immediately."

7.4 Taconite Mine, U.S.A.

In 1982 at the Cleveland Cliffs Empire Mine in Palmer, Michigan, a huge chunk of taconite ore caught in the conveyor structure and started to rip a 670 metre belt. The Sensor Guard system shut the belt down, limiting the rip to a minimum. If the belt had continued running to destruction, it would have cost Cleveland Cliffs at least five days downtime, $55 000 in installation labour, and $250 000 for a new belt. "Thanks to Sensor Guard we had to replace only 50 metres of belt. Without it, we would have lost the whole thing," said Bob Soderberg, mine maintenance superintendent. Repairing the rip required slightly more than a day and approximately $20 000.

Based on this experience Sensor Guard was added to a second belt, and Soderberg said, that all the mine's primary belts will eventually be protected by such a system.

"I've been in on the development of electronic belt protection from the experimental stage to now," Soderberg said. "I'm a believer."

7.5 Coal Mine, U.S.A.

"Don't ever let your guard down" is a saying usually associated with boxing, but it fits those in the mining business, too. Just ask Tom Pierce.

Pierce is construction foreman at Westmoreland Coal's, Big Stone Gap Mine. In 1985, a piece of metal punctured a small section of the plant's waste conveyor belt and in minutes destroyed the entire 1 098 metre length.

"That's when the belt didn't have Sensor Guard," he said. "Plant production was cut in half, and it took our own crews, five days of round-the-clock work to get the system back in operation. During that time, we had to bring in trucks to haul the waste."

Pierce estimates the ripped belt cost Westmoreland more than $200 000.

As fate would have it, history repeated itself at Big Stone Gap in 1986. But this time, Westmoreland didn't have its guard down -- Sensor Guard was part of the Flexsteel belt that replaced the competitor's ripped belt.

"It was almost an identical accident," Pierce said. "But this time, when the metal fragment punctured the Goodyear belt, only 4 metres was damaged because Sensor Guard did its job, stopping the system almost instantly."

Pierce estimated the replacement cost the second time around was a little more than $5 000.

"We were back in operation the next day, and I was sure thankful that we had Sensor Guard this time," he said. "We won't ever be without it now."

In each case, Sensor Guard protection enabled the facility to return to normal operation within hours of the accidents.

8. Conclusion

Every care should be taken in the design stage to ensure that chutes, scrapers and such do not contribute to belt rip's. However, they still occur all over the world. Literally, within seconds, they have the potential to cripple any operation which uses conveyor belts as the medium of moving it's bulk materials. It is suggested that the user look around and carefully weigh-up the systems outlined in this paper before reaching a decision.

For the cost of a couple of hundred meters of belting, a reliable system can be purchased which will not only reduce the amount of working capital tied up in spare belting, but will also ensure that you are not faced with an enormous, non-budgetted expense, in maintaining the supply of raw materials to your operation.

Statistics have shown that the rip rate can be as high as 20 per cent. Who knows, you may even be able to negotiate a reduced insurance premium, as is the case when business premises are protected by alarm systems for fire and burglary.

Remember, conveyor systems are just like cars in one respect -- both require belt protection for their valuable contents.