IMHC

INTERNATIONAL MATERIALS HANDLING CONFERENCE

BELTCON 4

Design of Load Chutes for Optimum Belt Life

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SUMMARY

The wear rate of a conveyor's top cover is governed by:

- Material abrasiveness
- Difference in velocity between belt and material
- Amount of 'give' at the load point
- Impact energy
- Angle at which the material strikes the cover

The relationship between these factors has been studied in a number of problem conveyors. The optimum chute design is such that wear life is maximised. Small variance from optimum design can result in an alarming increase in the rate of wear of the cover. It is often the case that two conveyors in series with very similar parameters return widely differing average belt life.

It is an accepted principle that the material should be loaded onto the belt in the direction of belt travel and at the same speed. In practice, this ideal is virtually impossible to acheive. Which factor will dominate in determining belt life? Is the conveyor chute design critical to ultimate belt life or will virtually any chute have the same effect on the life of the belt?

1. Introduction

How long should a conveyor belt last? Address this question to any conveyor belt manufacturer and receive a variety of answers that will be the envy of the best politicians. Why should the answer be so ellusive?

No literature is available on specifically how a so called "poor practice" will affect the life of the belt. We read that loading on an incline or loading at an angle to the line of travel lead to increased wear rate. But, is this practice worse than feeding from a greater height or any other alternative that may be necessary to achieve the desired "good" loading configuration.

This paper has the objective of presenting a reasonably accurate method of predicting belt life. As a corallary the factors influencing wear rate, and in particular the effect the loading can have on belt life are dealt with in some detail.

2. Amount of Wearable Cover

The starting point was a formula developed from the practical experience of an overland conveyor used at the Tarbela dam building project in India. Measurement of the amount of wear and the quantity of material conveyed were made. The rate of wear was graphed and the result was to highlight a very important principle. That is the amount of wearable cover or usefull cover guage. The graph of wear rate versus cover thickness developed from results of measurement of cover thickness and tonnage conveyed is given in figure 1. It is seen that wear rate for any given set of conditions is constant above a critical thickness. Below the critical thickness wear rate increases significantly. It is this critical thickness that must be subtracted from the total cover thickness to arrive at the amount of wearable cover. Later results from a conveyor system carrying crushed rock were used to further develop the model.

Obviously it is desirable to start with covers in excess of the critical thickness. The minimum cover guage is the value of the cover thickness at which the wear rate is unity. Most belt manufactures print tables similar that in appendix A as a guide to cover thickness for various categories of material. Certain belt constructions may require a cover guage in excess of the minimum arrived at in the way described. The manufactures literature should be consulted.

3. Formula for the Prediction of Belt Life

Based on the field experience a formula was drawn up to determine the amount of material that could be conveyed before the belt cover wore through.

Belt Life = $f_1 . C_T . t . T . D$ (1)

- C_T The cycle time or ratio between belt length and speed (minutes)
- D Material density (t/m^3)
- f_1 Abrasiveness of the material conveyed.
- t The thickness of wearable cover (mm)
- T Tonnage conveyed per mm of cover wear (Mt)

The cycle time in minutes is calculated by the simple formula.

$C_T = (2L+3)/(60.S)$ (2)

- L Conveyor length (m)
- S Belt speed (m/s)

Combining (1) and (2) results in the formula in the form shown in (3).

Belt life = $f_1 . t . T . D . (2L+3)/(60.S)$ (3)

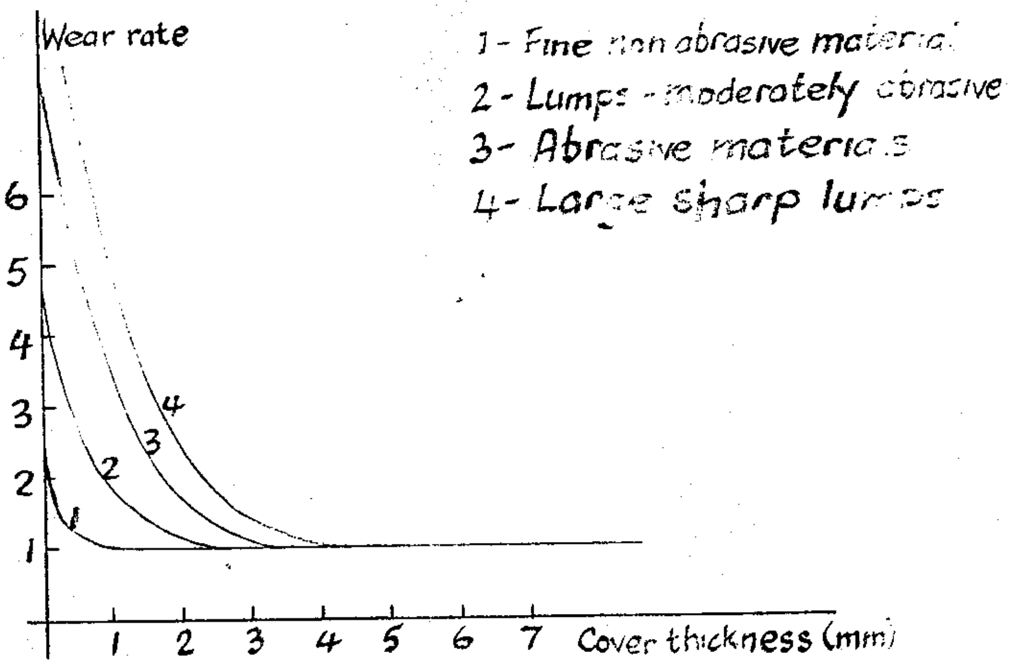


Figure 1 - Wear rate versus cover thickness

Belt width	CONDITIONS OF OPERATION Good	Average	Poor
750	0,75	0,50	0,20
900	1,25	0,75	0,30
1050	1,75	1,10	0,40
1200	2,25	1,35	0,50
1350	3,00	1,85	0,65
1500	3,75	2,30	0,85
1800	5,50	3,35	1,25
2100	7,50	4,35	1,65

Figure 2 - Anticipated wear rate of cover (Mt/mm)

Values for the tonnage conveyed per millimetre of cover are given in figure 2. These values having being obtained from actual field studies. Predictably, the belt width has an influence on the amount of material that can be conveyed for a given loss of cover guage. The amount by which the tonnage increases is directly proportional to the increase in capacity. Capacity of a belt is related to the troughing angle. The values given in figure 2 relate to a 35 degree troughing angle and must be adjusted downward for 20 degree troughing angle and upward for troughing angles greater than 35 degree. The amount of the adjustment is in direct proportion to the increase or decrease in belt capacity.

To ensure that the formula has any validity it is necessary to clearly define good, average and poor conditions. These conditions relate to the loading area where virtually all wear takes place.

Good conditions - Belts loaded to more than 60% of there maximum capacity with fine material or a mixture of materials with the fine content loaded first.

Average conditions - Belt loaded to more than 60% of its capacity with lumpy material.

Poor conditions - Freshly crushed material with sharp edges. Belt loaded to less than 60% of its maximum capacity.

4. Influence of Speed on Wear Rate

A factor in the cycle time is obviously the belt speed, but only in that this influences the frequency of any portion of belt visiting the load zone. An important influence on wear rate is the velocity difference between the belt and the material being loaded onto the belt. Referring to figure 3, the material flows down the chute with velocity V_2. Relative to the plane of the belt, in the load zone, the material velocity has horizontal components V_h and a vertical component V_v. Define the

difference between the belt speed and V_h as the material speed; the rate of wear is proportional to the square of the material speed so defined, as depicted in figure 4.
For the formula 3 to be valid the final life in tonnes must be divided by the wear rate value read from figure 4 relating to the velocity difference. Sometimes the formula is written in a form that assumes the material strikes the belt with no velocity component in the direction of belt travel as follows:-

$$\text{Belt life} = f_1.t.T.D.(2L+3)/(60.S^2) \qquad (4)$$

5. Angle of Impingement

The wear rate of a cover is also dependent on the angle at which the material strikes the belt. The relationship between rate of wear of rubber and the angle of impingment is not linear as seen in figure 5. The wear rate rises rapidly as the angle increases up to an angle of about 22 degrees where it is immeasurably high. The wear rate then decreases rapidly for angles from 22 degrees to 50 degrees, after which the slope of the curve starts to flatten until an optimum rate at 90 degrees. It is desirable to keep the angle above 50 degrees since small changes in angle have less serious consequences in terms of wear rate. A 50 degree angle represents a wear rate of 3. In terms of a moving belt, the impingment angle is the effective angle taking into account the direction of travel of the material and the difference in speed between the belt and the material. Referring again to figure 3, where V_v is the velocity of the material in a vertical direction relative to the belt, V_h the horizontal velocity and S the belt speed, then the effective angle of impingment is:

$$\text{Effective Angle} = \arctan\,(V_v/(S-V_h)) \qquad (5)$$

Plotting the velocity ratio $(V_v/(S-V_h))$ against effective angle results in the graph shown in figure 6. To keep the wear

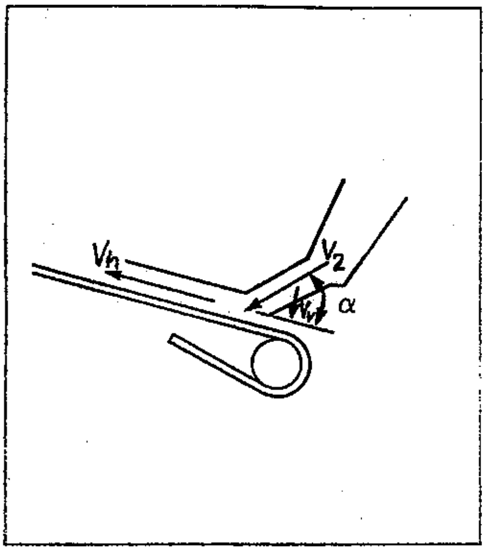


Figure 3 Chute layout

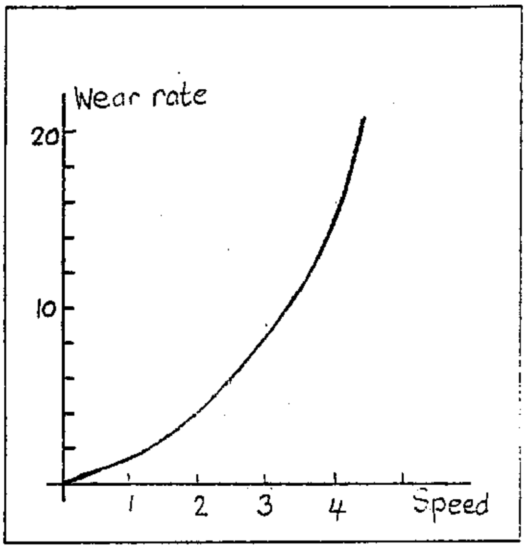


Figure 4 Wear rate vs Speed

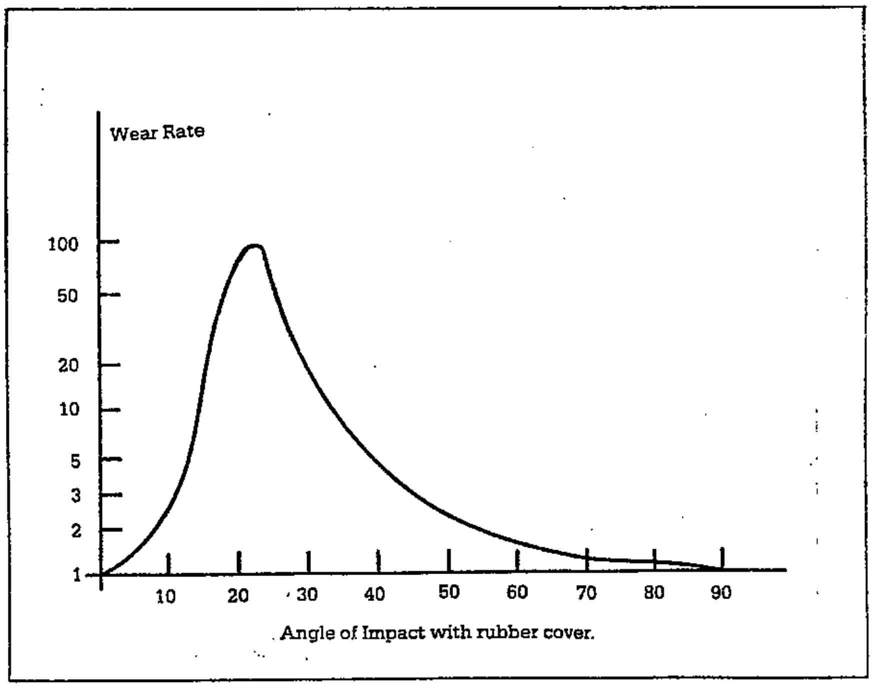


Figure 5 Wear rate vs Angle

rate less than 3 the effective angle must be smaller than 7 degrees or larger than 50 degrees. This means that in the case of a positive velocity ratio, ie, belt speed greater than horizontal material flow rate, the velocity ratio must be less than 0.1 or greater than 1.2. For material flow rate greater than the belt speed, the ratio should be less than -8.2 or greater than -0.9.

If the belt is inclined at the loading point, it is difficult to avoid large differences in speed between the material and the belt. In figure 7 the ratio between horizontal and vertical velocities for different angles is tabulated. In the case of an inclined belt, the angle of flow of the material is effectively increased by the amount of the incline. Suppose, for example, the chute angle is 50 degrees to the horizontal and the belt inclined at 15 degrees then the angle relative to the belt is 65 degrees. Reading from the table it is seen that the horizontal speed, or the speed in the direction of the belt, is 0,466 times the vertical speed. If the belt was not inclined the ratio is 0.839. This means that inclining the belt has nearly halved the velocity component in the direction of belt travel.

5.1. Case study to highlight the effect of impingement angle

A 600 metre long conveyor fitted with steelcord reinforced belting conveying limestone. Cover wear in the vicinity of the idler junction took place very rapidly. As is typical in the case of steelcord reinforced belts the wear rate was higher immediately above the cords than elsewhere. Cords were exposed in two narrow zones on either side of the centre line of the belt while in the centre the cover guage exhibited only minor loss due to wear (see figure 8). Investigations revealed that the chutes had been modified soon after commissioning, to allow a faster flow of material. The result was that material was striking the belt on the inclined edges instead of only in the flat centre (figure 9). The troughing angle was 90 degree. The material was falling at

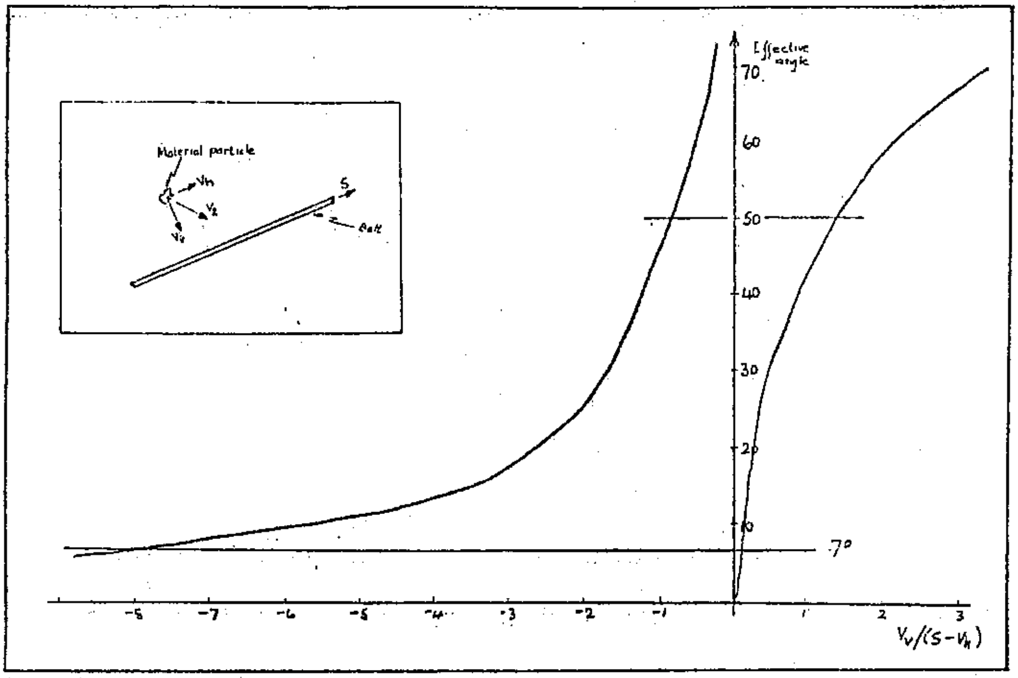


Figure 6 - Velocity ratio vs effective angle

ANGLE OF FLOW θ	COS θ / SIN θ
30	1,732
35	1,428
40	1,191
45	1,000
50	0,839
55	0,700
60	0,577
65	0,466
70	0,363
75	0,267
80	0,176

Figure 7 - Velocity ratio

approximately 80 degree to the horizontal. On the inclined belt edges the effective angle of impingement was 45 degree. From figure 5 the wear rate at the idler junction is predicted to be 4 times higher than in the centre of the belt.

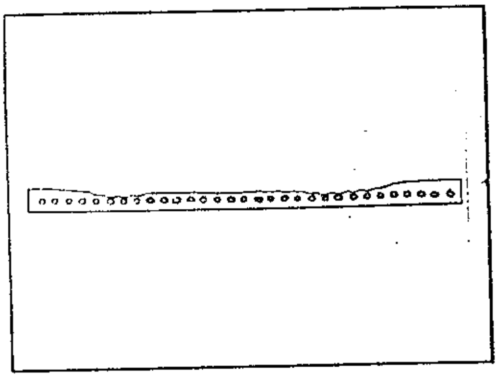


Figure 8
Wear of steelcord belt

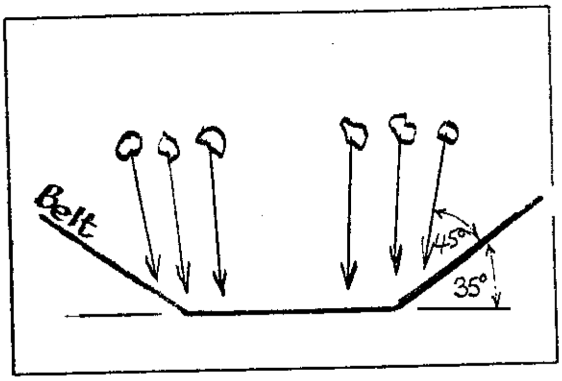


Figure 9
Section through the load

6. Impact at the Loading Point

Impact damage is one of the greatest causes of belt damage and yet there is very little practical research in this field. Impact test rigs have been built by various organisations. At best these rigs can measure the relative performance of belts without being able to predict what might happen in any specific application.

6.1. Impact Energy

The impact energy must be absorbed by the belt. The magnitude of this energy is related to the mass of the lump and the distance through which it falls. Values for the impact energy that can be absorbed by a belt have been published. A typical table of values is given in appendix B. These values are not specific but relate merely to the type of reinforcement material. It should also be born in mind that these values are measured by dropping a load vertically onto the test sample. As is the case with wear rate, the resistant of the rubber cover to cutting and gouging is also related to the angle of impingement. Consequently, the values published for impact resistance need to be corrected by a value derived from the graph in figure 5 to be of any practical value. The distance through which the belt can deflect will also have an influence on the amount of impact energy that can be absorbed wiuthout damage to either the cover or belt carcass. This distance is a function of the tension, belt modulus and idler spacing and these factors all play a part in the amount of impact energy that can be absorbed.

7. Conclusion

The design of the load chute can have a significant influence on the life of the belt. Not only can the loading chute influence the rate of wear but also whether the belt is damaged. The formula for predicting belt life can be used to estimate the tonange that will be conveyed by a belt. If the actual life is significantly less than predicted then this alerts one to the fact that optimum loading conditions are not being achieved.

REFERENCES

Conveyor Equipment Manufactures Association. Belt Conveyors for Bulk Materials, 2nd ed. Boston, Massachusetts: CBI Publishing Co. 1979.

APPENDIX A

RECOMMENDED COVER THICKNESS OF COLD BULK MATERIALS WITH NORMAL LOADING CONDITIONS

Non-abrasive material such as fertiliser, wood chips, grain pea coal. Lump size (mm)

Lap Ratio	Cover Type	Dust to 10	11 to 40	41 to 125	Over 125
12	N	2.5	5	8	10
	M	1.6	3.2	6.3	8
25	N	1.6	2.5	5	6.3
	M	1.6	2.5	3.2	5
40	N	1.6	2.5	3.2	5
	M	1.6	2.5	3.2	5
60	N	1.6	2.5	3.2	5
	M	1.6	2.5	3.2	5
90	N	1.6	2.5	3.2	5
	M	1.6	2.5	3.2	5
120	N	1.6	2.5	3.2	5
	M	1.6	2.5	3.2	5
180	N	1.6	2.5	3.2	5
	M	1.6	2.5	3.2	5
240	N	1.6	2.5	3.2	5
	M	1.6	2.5	3.2	5

Abrasive material such as salt R.O.M. coal, limestone, anthracite. Lump size (mm)

Lap Ratio	Cover Type	Dust to 10	11 to 40	41 to 125	Over 125
12	N	5	10	-	-
	M	3.2	10	10	6.3
25	N	2.5	5	10	-
	M	2.5	3.2	6.3	10
40	N	2.5	3.2	5	6.3
	M	2.5	3.2	4	5
60	N	2.5	3.2	4	6.3
	M	2.5	3.2	4	5
90	N	2.5	3.2	4	5
	M	2.5	3.2	4	5
120	N	2.5	3.2	4	5
	M	2.5	3.2	4	5
180	N	2.5	3.2	4	5
	M	2.5	3.2	4	5
240	N	2.5	3.2	4	5
	M	2.5	3.2	4	5

Very abrasive material such as slag, coke, copper-ore, sand, dolomite rock. Lump size (mm)

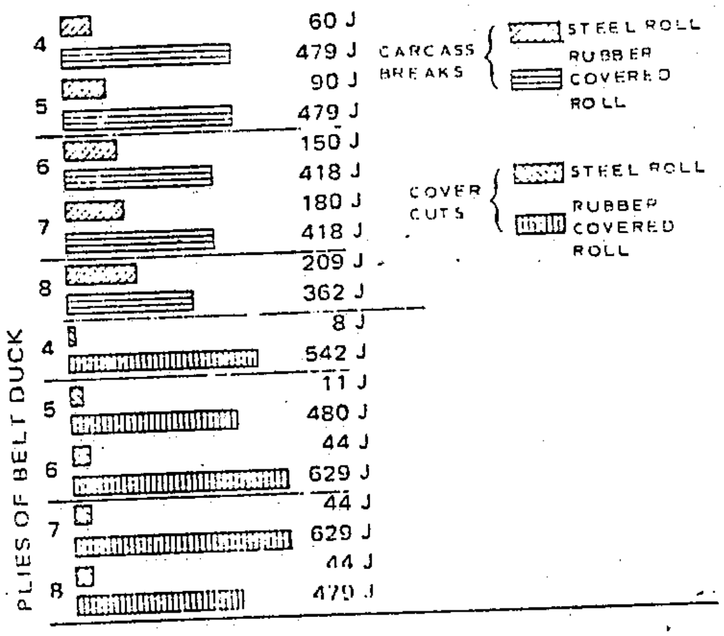
Lap Ratio	Cover Type	Dust to 10	11 to 40	41 to 125	Over 125
12	N	8	-	-	-
	M	10	10	10	8
25	N	5	8	-	-
	M	3.2	6.3	10	10
40	N	3.2	4	8	-
	M	3.2	3.2	6.3	10
60	N	3.2	3.2	6.3	10
	M	3.2	3.2	5	6.3
90	N	3.2	3.2	5	6.3
	M	3.2	3.2	5	5
120	N	3.2	3.2	5	5
	M	3.2	3.2	4	5
180	N	3.2	3.2	5	5
	M	3.2	3.2	4	5
240	N	3.2	3.2	5	5
	M	3.2	3.2	4	5

Very sharp material such as quartz, swarf glass, chrome ore. Lump size mm

Lap Ratio	Cover Type	Dust to 10	11 to 40	41 to 125	Over 125
12	N	10	-	-	-
	M	10	10	10	-
25	N	5	10	-	-
	M	4	8	10	10
40	N	3.2	6.3	10	-
	M	3.2	4	8	10
60	N	3.2	5	10	-
	M	3.2	3.2	6.3	10
90	N	3.2	5	10	10
	M	3.2	3.2	6.3	6.3
120	N	3.2	3.2	6.3	10
	M	3.2	3.2	5	6.3
180	N	3.2	3.2	5	6.3
	M	3.2	3.2	5	6.3
240	N	3.2	3.2	5	6.3
	M	3.2	3.2	5	6.3

Lap Ratio $= \frac{L}{S}$ where L = Belt length in metres; S = Belt speed in metres per second.

APPENDIX B



ENERGY ABSORBED BY BELT AND SUPPORT WITHOUT DAMAGE TO BELT