BELTCON 1

BELT CONVEYORS - DESIGN, OPERATION AND OPTIMIZATION

PAPER B6

DEVELOPMENT OF THE CABLE BELT CONVEYOR

Ian Main Thomson BSc (Eng.)

Managing Director
Cable Belt Ltd

University of the Witwatersrand
S.A. Institute of Materials Handling
S.A. Institution of Mechanical Engineers

SUMMARY

The early development of belt conveying is discussed showing how the Cable Belt system developed from the same requirements. The various design concepts are compared with those of the troughed belt conveyor highlighting the areas of advantage and disadvantage.

The areas of conveying where the Cable Belt system is most useful and the likely developments are outlined. These and other developments have led to many major conveyor installations including a 2 flight 52 km system being constructed to the Cable Belt design.

DEVELOPMENT OF THE CABLE BELT CONVEYOR

The origin of the belt conveyor is not easy to clearly identify but there are references to simple forms as early as 1795. However it was not until the dramatic increase in the world trading of grain after 1850 that major improvements were made[1].

The first form of conveyor was a flat belt running in a trough which was quickly improved by the introduction of straight idlers to replace sliding friction by rolling friction. The need to increase the capacity and centralise the material load led to the appearance at the same time of both of the most common forms of heavy duty belt conveyors, the troughed belt conveyor and the Cable Belt conveyor.

In the late 1860's the use in troughed belt conveyors of straight rollers with conical or dished ends was common, not becoming obsolete until the early 1890's. The introduction in 1865 of inclined straight 'concentrator' idlers led to the conveyor in the Thomas Robins Jnr. patent of 1896, which is regarded as the first troughed belt conveyor. Since that date whilst there have been many important improvements in the detail of the idler, belt and drive construction, the basic concept of the troughed belt conveyor is the same as outlined in the work completed in the early 1900's.

The Cable Belt conveyor principle whilst of earlier origin was not developed in a truly successful form until 1952. One of the earliest forms was that developed in 1859 and shown in the sketch fig. 1. This consisted of two parallel endless leather or rubber belts to which were attached at intervals curved metal spreaders supporting a canvas trough. There were many other similar conveyors but they all suffered from the same basic defect that the carrying belt was rigidly attached to the driving belts. This led to the disadvantages that the drive belts do not stretch alike and that the spreader bars are stressed and eventually break free from the drive belts.

The Cable Belt system successfully overcame these defects and since its introduction has generally been accepted in the conveyor field for long distance applications. A substantial proportion of the single flight conveyors over 5 km long that have been installed are now of the Cable Belt design.

The fundamental design differences made in the Cable Belt system were to use a round drive belt in the form of a wire rope, and not to attach the carrying belt to the drive belts. The first of these changes was aimed at getting over the difficulty of training to run in parallel a pair of flat belts by substituting positively located round cables running in grooved pulleys.

The second change was the point that allowed the Cable Belt system to operate successfully in contrast to the other earlier attempts. The carrying belt merely rests on the drive cables, these cables sitting within shoes which are moulded on the belt surfaces. It may seem that depending on friction alone the Cable Belt is liable to have the belt slip backwards on the drive cables. However as all belt conveyors depend on friction between the belt and the material carried to allow them to operate at all, the only requirement is that the friction between the belt and the drive cables should be greater than between the belt and the material. This was achieved by shaping the belt shoes to grip the drive cables.

It has been possible using Cable Belt belting with specially formed surfaces to run on slope conveyor systems where the overall grade is 21°, and with particular sections of 28°, without experiencing slipping of the belt on the drive cables.

Whilst the Cable Belt conveyor was developed at a time when the powers available of up to 300 kW were regarded as outstanding the basic concept is still retained even when now, single conveyors of 30000 metre length and 8000 kW power are being built.

The Cable Belt is best defined as a belt conveyor with a laterally rigid but longitudinally flexible carrying belt which is supported at or near its edges on two parallel endless loops of drive cable, these cables in turn being supported at intervals by grooved pulleys. The integral reduction gear and drive unit drives both drive cables and incorporates a differential to equalise tensions in the cables. In addition each of the drive cable circuits is separately tensioned to allow for the differential stretch of these during operation.

The unique feature of the Cable Belt system is the belt. Originally this was a fabric reinforced rubber belt which had moulded into it spring steel straps at 450 mm intervals. These straps protruded beyond the edges of the belt as illustrated in fig. 2, and had mechanically attached to them a metal shoe with rubber lining where it gripped the drive cable. This was superseded by a one piece moulded construction shown in fig. 3 where smaller cross section straps at intervals of 100 mm were moulded entirely within the belt and the shoes to grip the drive cables were continuous mouldings along the edge of the belt.

Recently a further change was made, illustrated in fig. 4 whereby the shoes which grip the drive cable on the material carrying run have been moved inwards. This increases the stability of the belt when subjected to overloading and in addition allows the use of smaller cross section straps.

It is normal that on a typical long centre conveyor the eventual replacement of the belt is not for reasons of abrasion of the surface or mechanical damage, but due to the various ageing processes that affect rubber compounds such as heat, sunlight, and ozone. As a result it has been necessary to develop special synthetic rubber compounds that are inherently resistant to ageing.

The specification of the drive cables whilst similar superficially to a normal wire rope are specially made to a Cable Belt specification with design criteria laid down for individual wire size, fatigue life and internal lubrication. They are of galvanised construction, Lang's Lay with either a fibre or wire rope core. Currently they are used in sizes up to 60 mm diameter and breaking loads of 260 tonnes. As this is the tension reinforcing member of the Cable Belt system great attention is paid to reducing the number of splices and drive cables of up to 100 tonnes weight for each section have been used.

Along the line of the conveyor it is supported at intervals of between 5 and 10 metres by grooved pulleys approximately 300 mm in diameter. Previously these pulleys were of a hardened steel construction but the current design is for a pulley with a replacement rubber lined tread. These pulleys are mounted in pairs on articulated arms which allow the conveyor to self align and equalise the loads on each pulley as can be seen in fig. 5.

The terminal units are similar to those in a conventional troughed conveyor except that they also serve to separate and rejoin the carrying belt and drive cables. A typical example of a head discharge unit is shown in fig. 6. Obviously the terminals other than the drive unit are more complex than in a conventional troughed conveyor and take up more space particularly in the case of the tensioning arrangements. This is not true of the drive as for a comparable power rating it is compact and has the advantage that it can be located remote from the Cable Belt conveyor belt line.

As the modulus of elasticity of the drive cables is kept relatively low in order to allow the use of very low starting torques and each drive cable is tensioned, the tension system does require substantial take-up space and is more complex as is illustrated in fig. 7.

The concepts behind the design of the Cable Belt conveyor are very similar to a conventional conveyor in that there is conveyor friction and the vertical alignment is a series of catenaries, but of course the factors used vary considerably because of the different characteristics.

The conveyor friction losses are considerably reduced principally because of the significantly lower number and weight of moving parts in a comparable system.

This reduction is normally in the order of 30%. In addition the friction losses due to the working of belt and material as they pass over the idlers are significantly less. It has been determined empirically that there is in the order of a 10% reduction in the friction losses.

The establishing of the facts, even on a comparative basis, with regard to conveyor friction has proved difficult as all the data is empirical and the various design standards can show markedly different results. In addition conveyor friction will vary with temperature, age and standards of installation and maintenance. However in a recent major installation it has been possible to compare the friction values, at least on a design basis and as can be seen below these bear out the differences.

	Conventional	Cable Belt
Number of Rotating Parts	100	76
Weight of Moving Parts	100	64
Friction Losses	100	67

In determining the vertical alignment of the Cable Belt system whilst the formulae and calculation are the same, great care must be exercised as it is not possible to allow 'lift off' in catenaries to occur.

Whilst this condition is normally avoided in all conveyor design, it is essential, to prevent derailment of the drive cables, to design catenaries correctly and conservatively.

As is well known the normal catenary formulae are approximations which allow a factor of safety against 'lift off'. In designing the Cable Belt system the same formulae and factors are used, but effectively the protection against 'lift off' is increased by determining worst possible loading conditions and limiting the starting torques. This situation is helped in that the conveyor friction is such and modulus of the drive cables is selected to ensure that there is virtually no additional breakaway torque required even to start a long flat overland Cable Belt system.

The major difference in designing a Cable Belt conveyor lies in the separation of the carrying belt and the drive cables. Whilst good design practice requires that they should be kept together, the ability to separate them does give considerable flexibility in design and allows the introduction of concepts unknown in the conventional belt conveyor. The most widely used of these is in the many circumstances where a straight line route or one incorporating curves is not feasible, and the unit known as an angle station is employed. As can be seen from fig. 9 this allows any angle up to 320° to be accommodated and still retain the feature of a single drive but incorporate two separate carrying belt circuits. This feature is used in about 30% of the Cable Belt installations.

The other concept that is widely used is as mentioned earlier, the ability to place the drive unit remote from the belt line. This feature, which is unique, allows the drive unit and its associated electrical equipment to be located in a position with easy access for maintenance but away from the dust and dirt associated with a conveyor discharge or return belt line. This flexibility also allows the drive unit to be placed at any point in the conveyor, including if necessary on the material carrying run of the drive cables.

The other part of the Cable Belt design that is unique is the tensioning system and there is no doubt that this is more complex and takes greater space than would be required in a troughed belt conveyor. There are several reasons for this but the principal reason is the necessity to provide equipment to separately tension each drive cable and the carrying belt. Whilst the tension in the carrying belt is nominal it is still necessary to cater for the drive cable tension movement, particularly in long flat conveyors which, of necessity, are tensioned at or near the drive unit. In such conveyors the tension movement of the drive cables is substantial during the start sequence. Before the whole conveyor is moving the effect is that it is necessary to 'store' in the carrying belt tension system a length of belt equivalent to the elastic stretch of the drive cables. This of course is released when the conveyor stops. In a typical 15000 metre long conveyor this stretch can be up to 80 metres.

The main reason for taking up a greater space than a troughed belt conveyor is the necessity to cater for both the permanent stretch and the relatively high elastic stretch of the drive cables. The permanent stretch of about 1% which occurs in the first few hundred hours of running could be eliminated during manufacture but it conveniently provides the necessary space for splicing of the cable as well as generating extra cable which can be used when resplicing is necessary. The choice of the modulus that governs the elastic stretch is a compromise between minimising the stretch to reduce the space requirements and having sufficient stretch to ensure very low 'breakaway' torques.

As can be seen from the foregoing information the Cable Belt system while fulfilling the same role in many ways is quite different from the troughed belt conveyor. As most conveyors are of short length and low horsepower there is no doubt that the troughed belt conveyor is the correct solution for many conveyor applications. However in those areas of long lengths or high lifts the Cable Belt system often shows decisive advantages and in those cases where its unique design concepts can be used it may be the only choice.

To define the precise applications which a Cable Belt system is suitable for is difficult, as nearly one third of the systems installed are in applications in which they were not the most competitive solution. In each case they were chosen for one of the unusual features that the system offers. As a general rule the Cable Belt in its current form is not technically suitable for short centre conveyors mainly due to the size of the terminals. In addition to the cost of the terminal equipment the main cost component of any belt conveyor, the belt, in the Cable Belt system has a constant cost irrespective of the power requirements. This loads the capital cost on low power conveyors but reduces it on high power conveyors in comparison with a troughed belt conveyor.

In summary the current competitive situation of the Cable Belt system appears to be :-

- In slope conveyors of less than 750 kW or level conveyors of less than 3000 metre length the Cable Belt is not the most competitive solution. Above these parameters the Cable Belt becomes increasingly competitive in capital cost.

- In level conveyors where the power due to friction losses is a substantial part of the total, the operating costs of the Cable Belt system are becoming increasingly attractive. In other cases there does not appear to be any significant differences.

There is one significant development of the Cable Belt system which is currently undergoing field trials. When generally available in the next few years it should, for the same capital cost, show a significant reduction in operating costs. This involves the production of a drive cable where the individual wire reinforcing strands are separately moulded within an elastomer giving a round steel and elastomer drive cable. Initial results have been most encouraging with a threefold increase in the fatigue life as against a conventional steel wire rope.

Recent developments in the Cable Belt system show that it can effectively compete with rail transport over distances which until now have not been regarded as suitable for conveyor systems. As an example there is currently being constructed in Western Australia for Worsley Alumina Pty. Ltd., a two flight, 52000 metre Cable Belt conveyor system.

To be operated by Worsley Alumina Pty Ltd., and located near Perth, W. Australia, this installation incorporates two Cable Belt conveyors in tandem and is an overland system which transports crushed bauxite from the mine to a refinery.

At the intersection of the two conveyors, the material is turned through 50° (to the left) by means of chutes and rock boxes and fed to the second stage Cable Belt conveyor.

Both the conveyors are single drive conveyors with their drive and tension units located at the transfer/discharge ends of each conveyor. To minimise spares holdings, the conveyors have been standardised with almost complete interchangeability of components.

LENGTH:		31000 m	21000 m
DIFFERENCE IN ELEVATION:	(Fall)	72 m	14 m
MATERIAL:		Bauxite	
DENSITY: (Specific Gravity)		$1520\ kg/m^3$	
RATED CAPACITY:		2040 m.t.p.h.	
ANNUAL TONNAGE:		$9{,}06 \times 10^6$	
BELT WIDTH:		900 mm	
OPERATING SPEED:		6,35 m/sec.	
DRIVE CABLE:		57 mm dia.	
LINESTAND PITCH:		4,75 m	
POWER:		5300 kW	3600 kW

In conclusion it would appear that the Cable Belt system has the capability of further development which should permit the expansion of belt conveying into even longer economic lengths than those currently under construction.

The Author wishes to acknowledge the assistance given by Worsley Alumina Pty. Ltd., and the Cable Belt companies in the preparation of this paper.

References:

1) Belt Conveying and Belt Elevators - Hetzel and Albright
John Wiley & Sons

2) The Fulling Resistance of Belt Conveyors - H.P. Lachman

APPENDICES

APPENDIX 1 - Belt Design

APPENDIX 2 - Cable Factor of Safety

APPENDIX 3 - Conveyor Friction Losses

APPENDIX 4 - Operational Information on Cable Belt Conveyor Systems

APPENDIX 1

BELT DESIGN

The design of the belt in a Cable Belt conveyor is straight forward in that the belt serves only one function, that of supporting the material.

The parameters and principles used in the construction of the components, steel rods, fabric and rubber, and the manufacturing techniques are similar to those in conventional belt design. The same requirements exist that the materials must resist corrosion, chemical attack from the materials carried, abrasion cutting and the ageing effects of the environment. In addition, the belt must be flexible and the components must finally act as one unit.

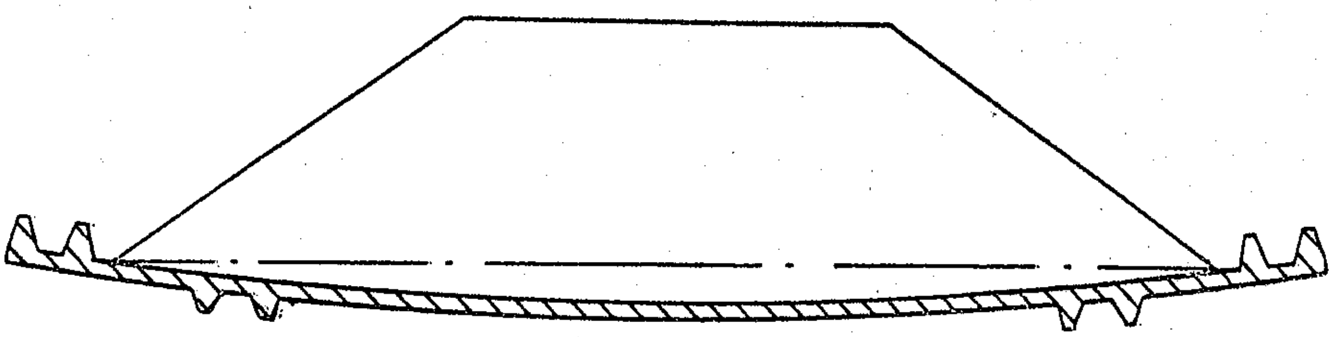
All of these requirements are met by employing conventional belt manufacturing techniques.

There are two calculations which are specific to the Cable Belt system, the calculation of the lateral stiffening required to support the material and the calculation of the material volume that can be carried.

Lateral Stiffness

The required lateral stiffness is provided by rectangular high tensile steel rods. In the calculation only the steel section is considered and the material load is considered to be of a combined trapezoidal and parabolic form acting on a simply supported double cantilever beam.

The selected steel rod section is governed by the material load to be supported, the deflection necessary to give the required material volume and maintaining the stresses in the steel rods within given criteria.



Carrying Capacity

On initial consideration it might seem that the carrying capacity of a Cable Belt conveyor being a "flat" belt will be less than a comparable conventional conveyor. However this is not so and generally comparing nominal widths the rated capacity of a Cable Belt conveyor is greater for a given belt width.

There are many reasons for this, but principally they are:-

1. There is significantly less working of the material in the Cable Belt system and even fluid materials such as alumina retain angle of repose close to the static angle of repose. This has been proven in long and undulating systems.

2. The effective width assumed in a conventional belt calculation is significantly less than the nominal and actual belt width whilst in the Cable Belt system and the effective width is very close to the nominal width.

3. The actual width of a Cable Belt belt is substantially greater than the nominal width and this combined with the raised edge provided by the shoe forms gives the ability to carry approximately 30% above the rated capacity without spillage.

4. The Cable Belt belting is not "flat" in that in the loaded condition the belt deflects and provides a parabolic shape which contributes up to 30% of the carrying capacity.

5. The positive tracking of the system allows the belt to be rated at or near its theoretical capacity.

In the table below can be seen a comparison for a material such as coal:

Belt Width	CEMA 45^{0} 3 Equal Rolls	CABLE BELT
915 mm	0.105 m^2	0.125 m^2
1067 mm	0.146 m^2	0.177 m^2
1219 mm	0.193 m^2	0.235 m^2

APPENDIX 3

CONVEYOR FRICTION LOSSES

As indicated all frictional losses are evaluated from empirically derived formulae. There have been theoretically based analyses, notably that of Dr. Lachman and we have attempted to apply his method of analysis to the Cable Belt system. "The Fulling Resistance of Rubber Belt Conveyors", B.P. Lachman. It is necessary to be cautious on the results but there are differences in the Cable Belt conveyor which when used in this analysis do approximately confirm values obtained from Cable Belt conveyors in the field.

Whilst the Cable Belt frictional losses are not calculated in precisely the same manner, the table below illustrates the friction factors used on a basis that can be compared.

CABLE BELT	CONVENTIONAL CONVEYOR
0.14	0.16 - 0.18

It is not possible to give definite reasons why this difference exists, but we believe that the following reasons are important.

- the working of the belt is less in the Cable Belt system as the troughed shape is built into the belt and is not provided by external forces.

- the working of the material for the same reason is also appreciably less, this is particularly noticeable in high speed conveyors.

- the size of the line pulleys and their design is such that the "Idler" loss is materially reduced.

APPENDIX 2

CABLE FACTOR OF SAFETY

Normal running factor of safety is normally between 3 and 4.

Of course the principal reason that the frictional losses are less is that in the Cable Belt system there is an appreciably lower weight of moving parts. We believe that the reasons for this are that in the Cable Belt system it is possible to design each element in the system to operate more efficiently and thereby reduce its weight.

Specifically the steel reinforcement in both the belt and cables is used in a more efficient manner and in addition large quantities of rubber are not used merely as a filler and tension equalising medium.

In a specific example in two conveyors of the same duty (1800 m.t.p.h. over 14730 metre length with 990 metre lift) the comparative weights are:

	CABLE BELT	CONVENTIONAL
Wt. of cable/metre conveyor	56 kg	NIL
Wt. of belt/metre conveyor	57 kg	176 kg
	113 kg	176 kg

Whilst these explanations may not seem definitive, the real proof lies in the field performance and the position is that using these derived factors both conventional and Cable Belt conveyor systems are built and both operate to their design parameters successfully.

As a further example the design and actual horsepowers from a Cable Belt system are compared with the design produced for an equivalent conventional system:

Length:	9909 metres
Lift:	15 metres
Capacity:	2000 s.t.p.h.
Belt Speed:	4,18 m/sec.

CONVENTIONAL DESIGN Power	CABLE BELT DESIGN Power	CABLE BELT ACTUAL Power
2050 kW	1645 kW	1475 kW

APPENDIX 4

OPERATIONAL INFORMATION

ON

CABLE BELT CONVEYOR SYSTEMS

A.) T:145/AMERICAN COMMERICAL TERMINALS

B) T:146/AMERICAN COMMERCIAL TERMINALS

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1. Summary

2. Technical Characteristics

3. Operating Characteristics

4. Life of Main Items

5. Site Conditions

6. Estimated Operating & Maintenance Costs to Date

SUMMARY

A) T:145/AMERICAN COMMERCIAL TERMINALS INC. - 9 - MILE SYSTEM

B) T:146/AMERICAN COMMERCIAL TERMINALS INC. - 3½- MILE SYSTEM

TECHNICAL CHARACTERISTICS

(A) T:145/AMERICAN COMMERCIAL TERMINALS

9-Mile System

Fifty percent belt changed after eleven years. One hundred percent change estimated after twelve to thirteen years.

Left-hand rope changed after 20.5 million tons (1977). Right-hand will achieve in excess of 30 million tons (eleven years). The left-hand rope was changed prematurely.

Approximate pulley changes 1.5 per running hour.

(B) T:146/AMERICAN COMMERCIAL TERMINALS

3½-Mile System

Startup Date: October 1971

Basic Characteristics

Material:	Crushed Coal
Density:	55 lbs/ft^3
Capacity:	1000 TPH
Speed:	700 ft/min.
Width:	36 inches
Length:	18,300 ft.
Lift:	Level
HP:	500 HP
Rope Size:	1½ inches
Linestand Pitch (Top):	25 ft.

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OPERATING CHARACTERISTICS

(A) T:145/AMERICAN COMMERCIAL TERMINALS

9-Mile System

System operates 7 days/week, 24 hours/day period. Maintenance carried out on day shifts only averages 14 to 16 hours/week. Personnel employed also operate yard belt (approximately 1800') 3500 t.p.a. stacker/reclaimer, barge loading facilities.

Number of personnel employed: 17 hourly paid
3 shift foremen
1 supervisor

Operating Characteristics - June 30, 1980

Tons Carried:	30,156,352
Hours Run:	27,237
Average Tons/Hour:	1,107.2
% of Design:	73.8%
Cycle Time:	2 hours
Number of Cycles:	13,618

(B) T:146/AMERICAN COMMERCIAL TERMINALS

3½-Mile System

System operates 7 days/week, 24 hours/day period. Maintenance carried out on day shifts only averages 14 to 16 hours/week. Personnel employed also operate yard belt (approximately 1800') 3500 t.p.a. stacker/reclaimer, barge loading facilities.

Number of personnel employed: 17 hourly paid
3 shift foremen
1 supervisor

Operating Characteristics - June 30, 1980

Tons Carried:	13,160,345
Hours Run:	16,983
Average Tons/Hour:	774.9
% of Design:	77.49%
Cycle Time:	52.3 minutes
Number of Cycles:	19,483

4

LIFE OF MAIN ITEMS

(A) T:145/AMERICAN COMMERCIAL TERMINALS

9-Mile System

Fifty percent belt changed after nine years. One hundred percent change estimated after eleven to twelve years. Guaranteed life ten years.

Left-hand rope changed after 20.5 million tons (1977). Right-hand will achieve in excess of 30 million (nine years). The left-hand rope was changed prematurely. Guaranteed tonnage 9.55 million.

Approximate pulley changes 1.5 per running hour.

(B) T:146/AMERICAN COMMERCIAL TERMINALS

3½-Mile System

No belt changed. Estimated life 11 to 14 years.

No ropes changed. Estimated life 10 to 12 years.

Approximate pulley changes 0.5 per running hour.

Overall pulley changes to date work out at about 1 pulley per running hour.

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SITE CONDITIONS

(A) T:145/AMERICAN COMMERCIAL TERMINALS

9-Mile System

Temperature varies between 105° F. maximum to -15° F. minimum. Overland system with 2/3-type cover subject to the elements. A number of bridges and elevated steelwork en route.

(B) T:146/AMERICAN COMMERCIAL TERMINALS

3½-Mile System

Temperature varies between 105° F. maximum to -15° F. minimum. Overland system with 2/3-type cover subject to the elements. A number of bridges and elevated steelwork en route.

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OPERATING AND MAINTENANCE COSTS

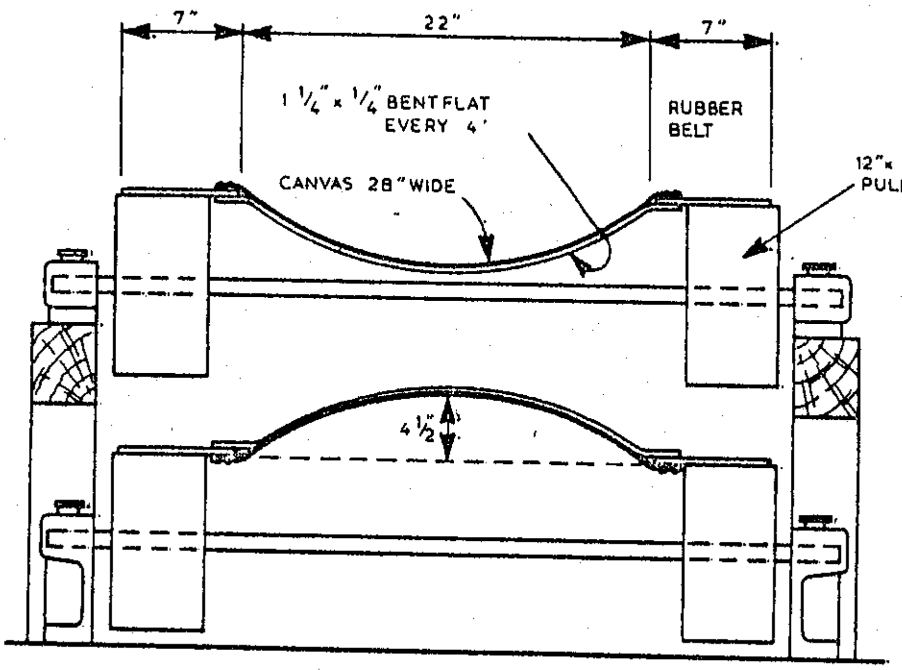
(A) & (B) T:145 & T:146/AMERICAN COMMERCIAL TERMINALS
12½-Mile System

Estimate O & M Costs to Date

Replacements (includes belt, rope, pulleys etc)	10 cents/ton
Personnel	10 cents/ton
Power	3 cents/ton
Total:	23 cents/ton
	= 1.84 cents/ton-mile
	= 1.14 cents/ton/Km

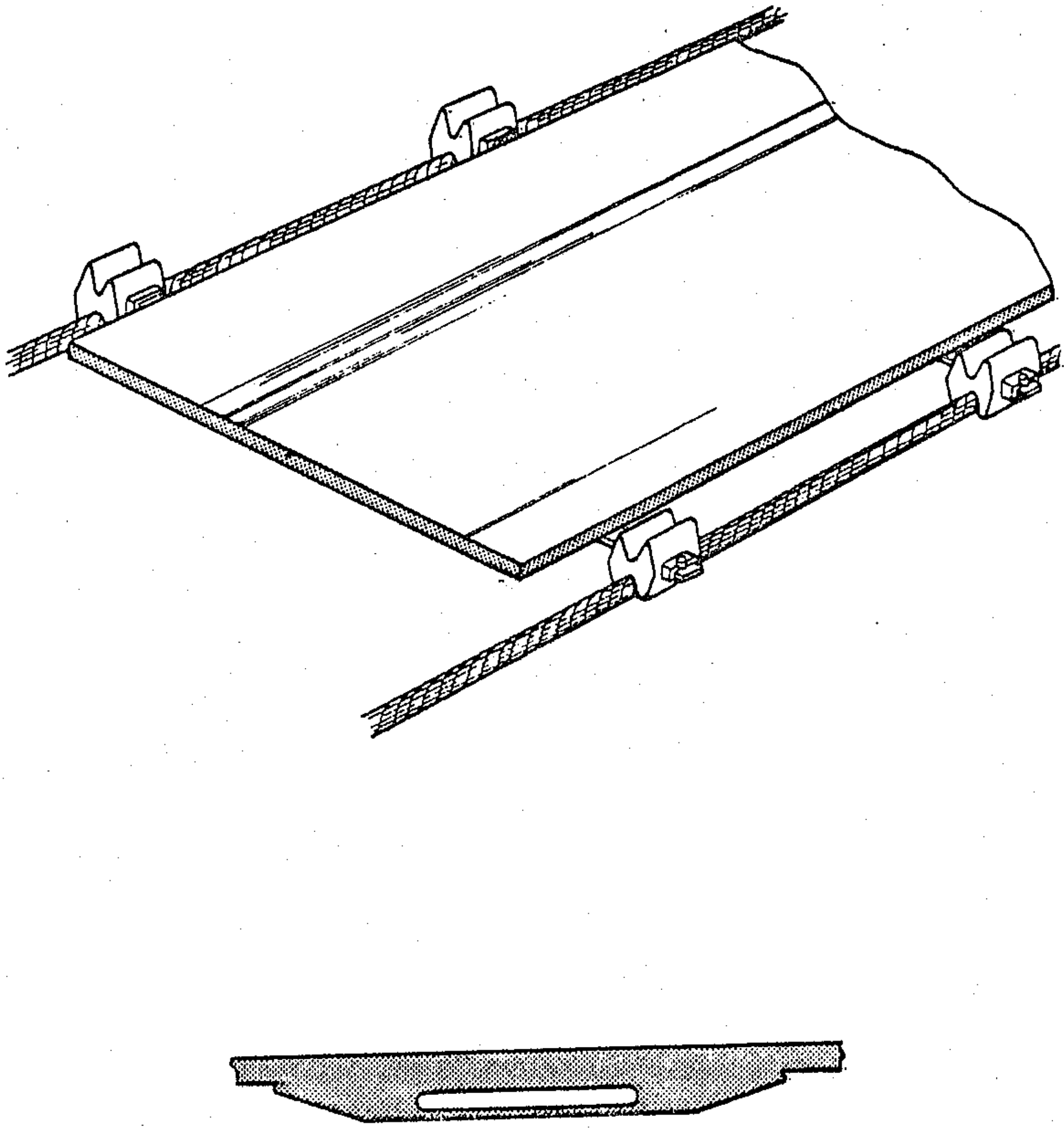
NOTE:- The above costs are in U.S. Currency.

FIG 1

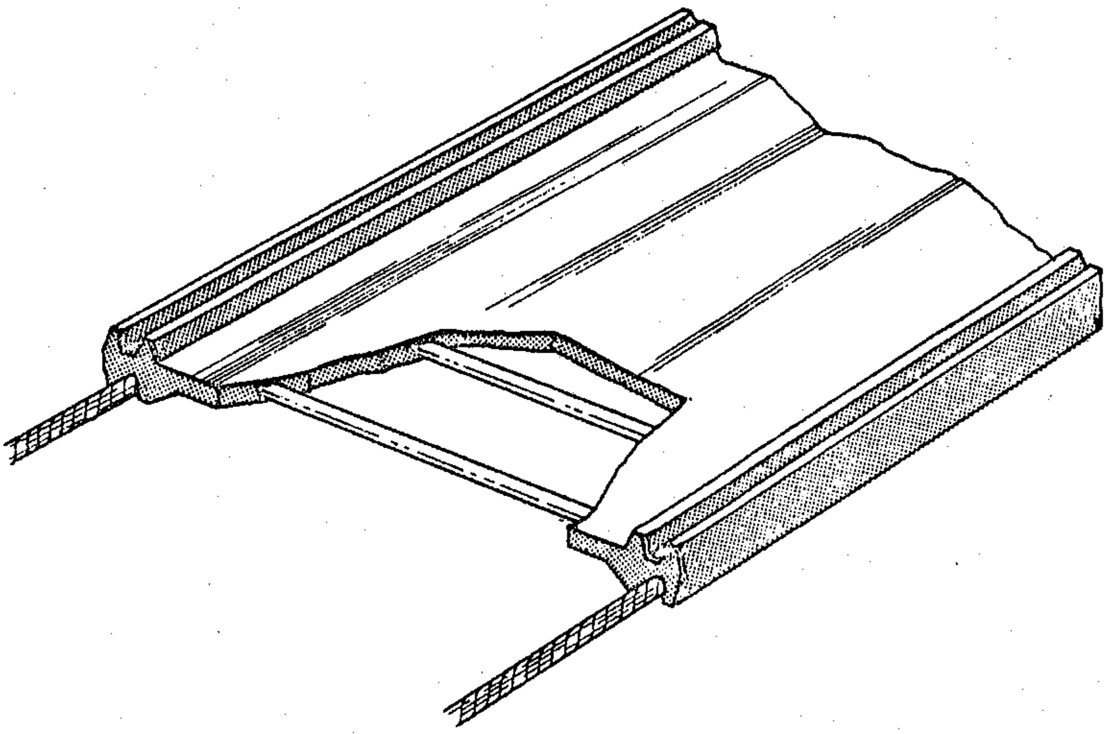


Early Belt Conveyor Fig 1

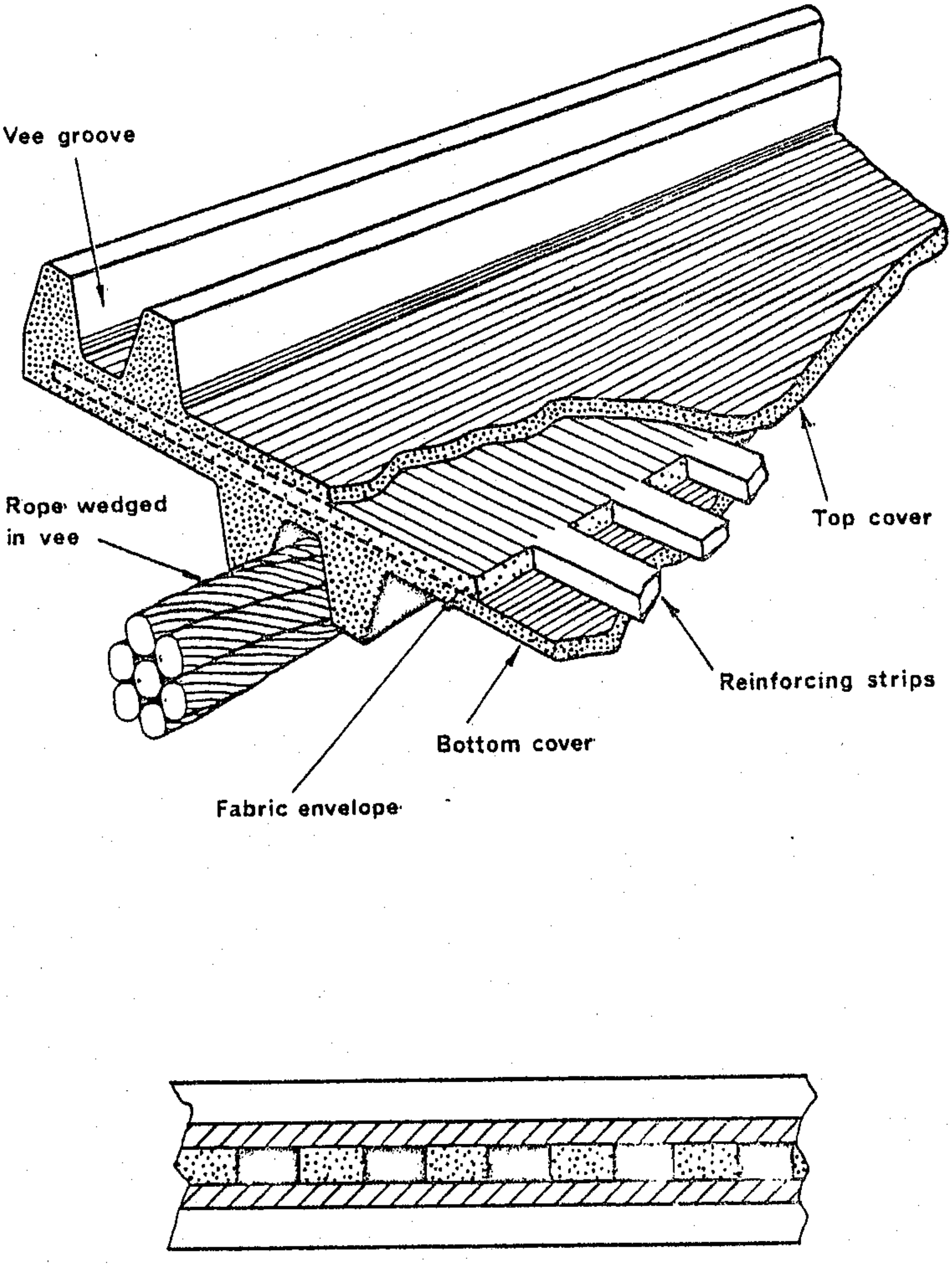
IG 2



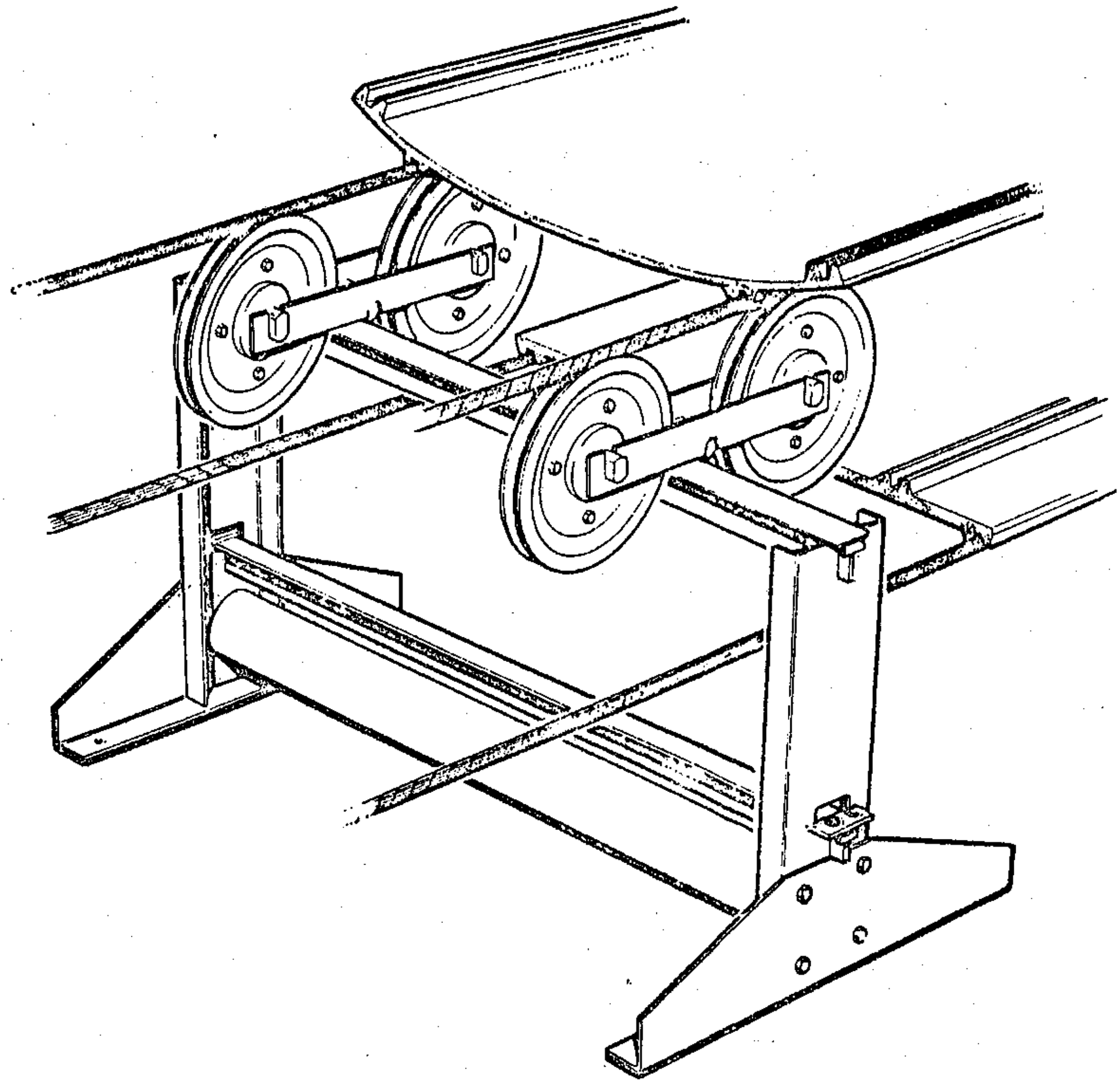
Early Cable Belt Belting Fig 2



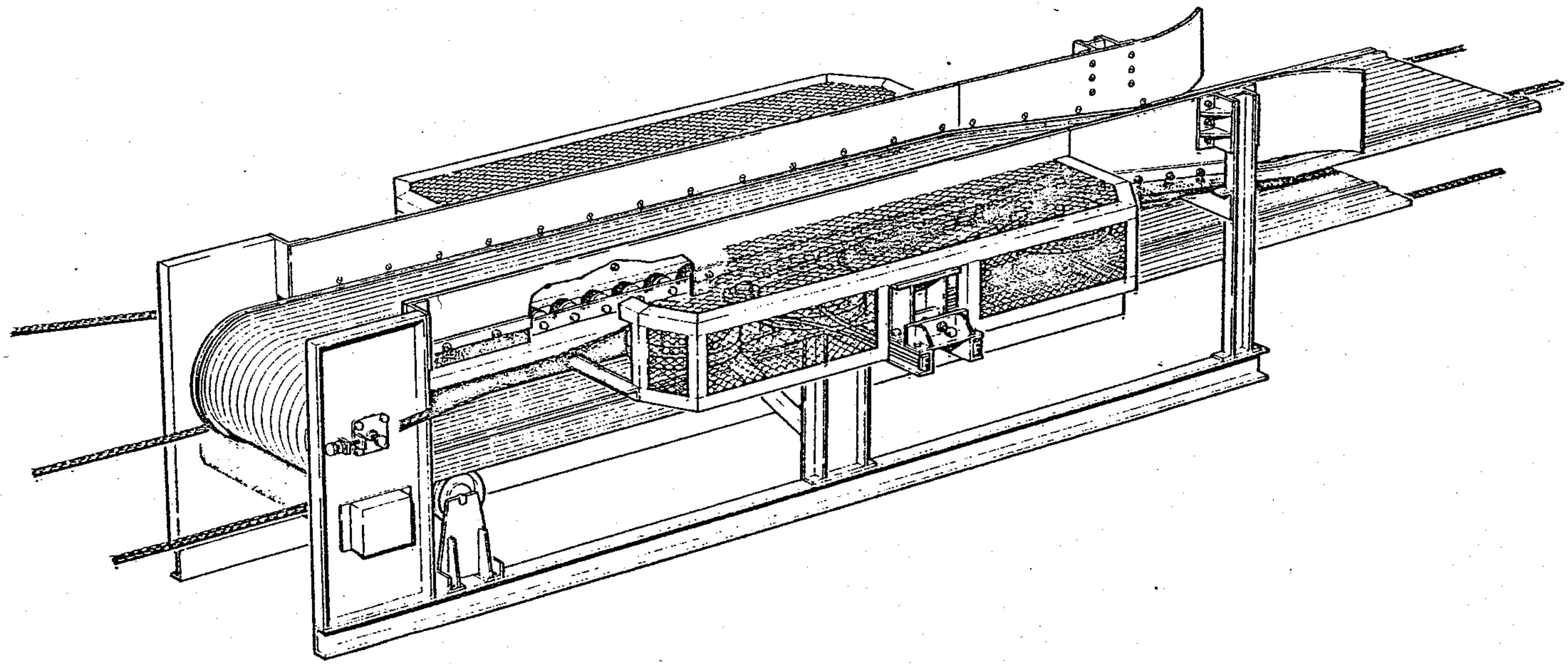
Intermediate Cable Belt Belting Fig 3



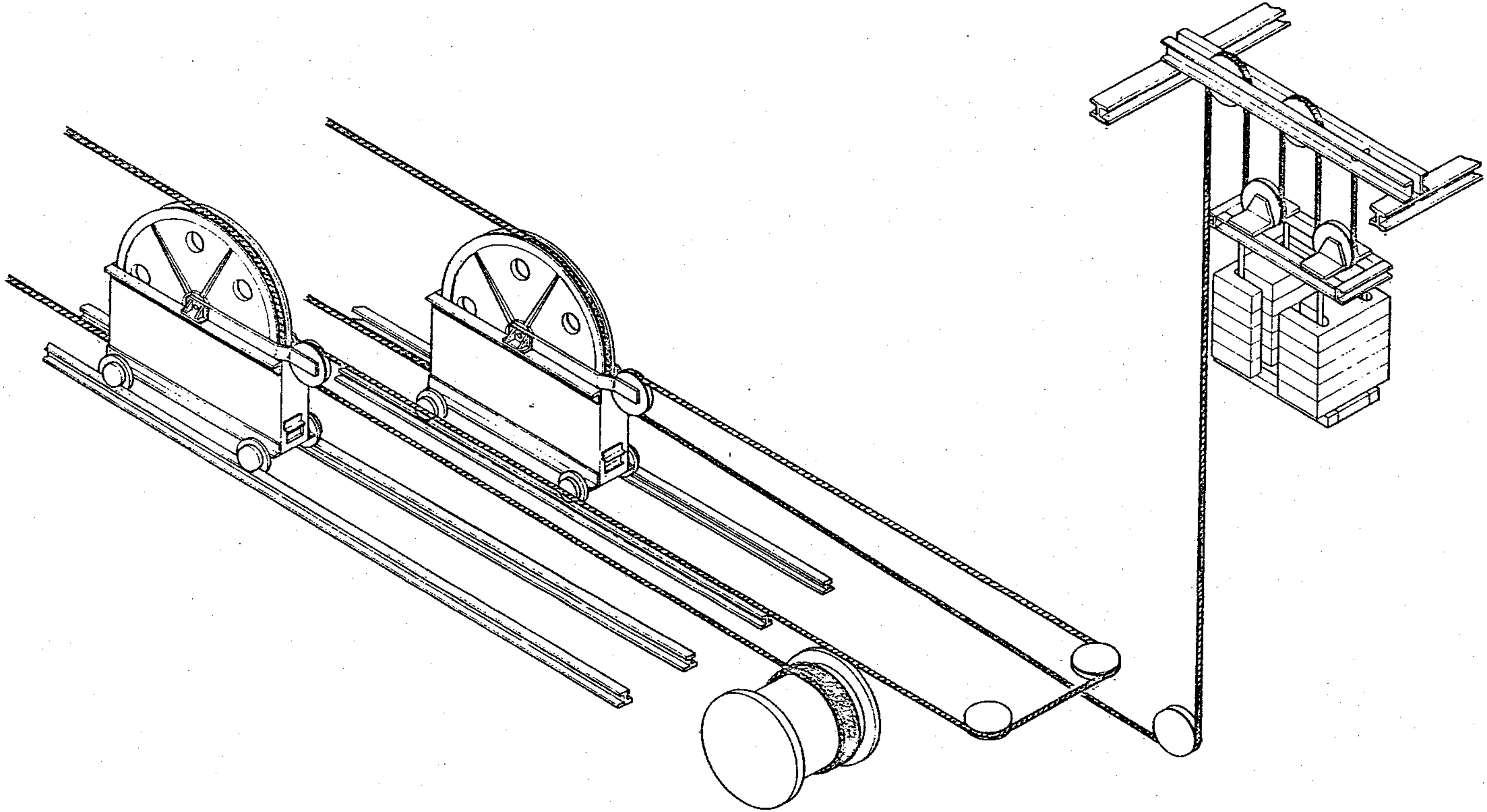
Modern Cable Belt Belting Fig 4



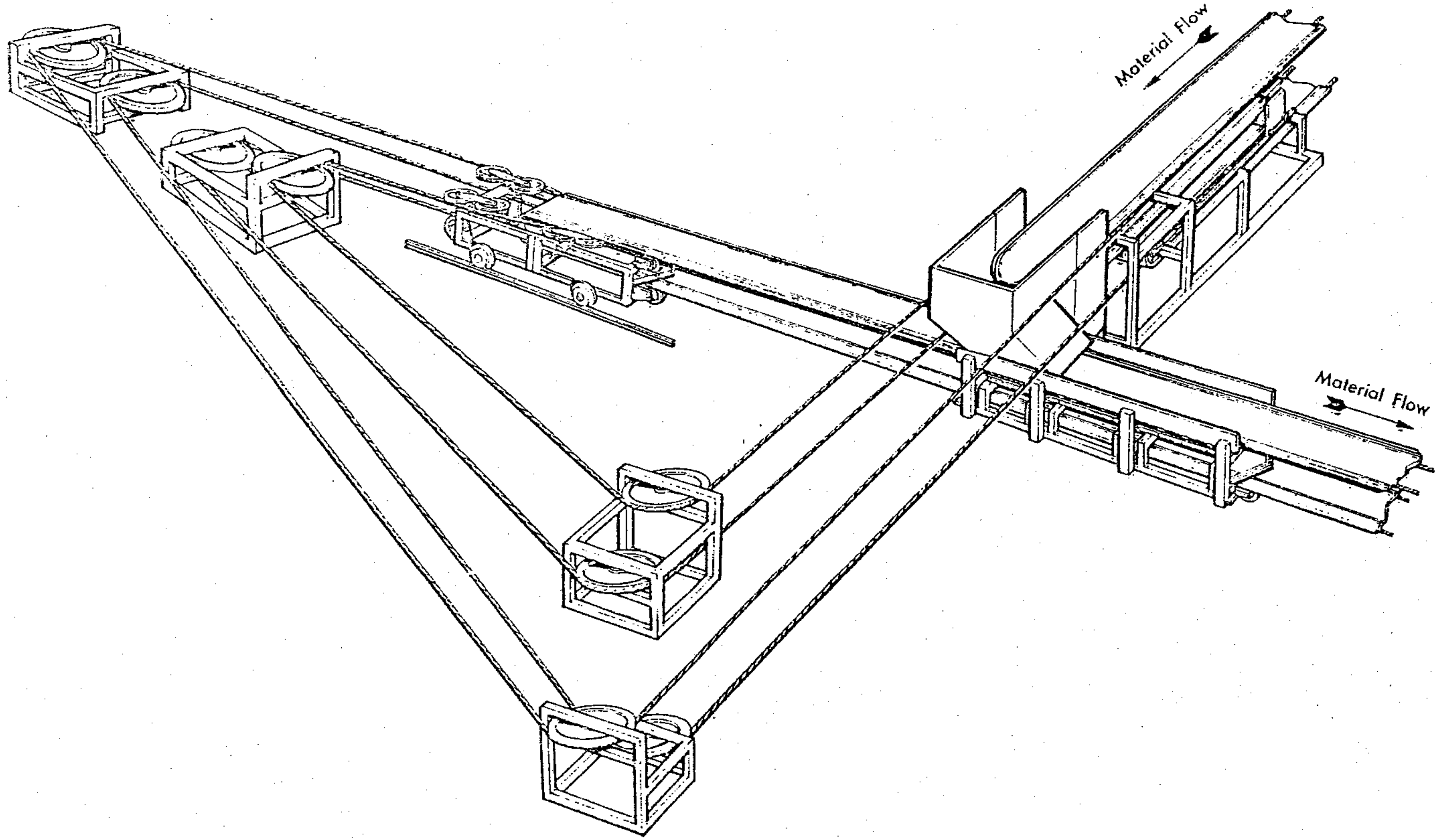
Typical 4 Pulley Line Stand Fig 5



Head Discharge Unit Fig 6



Typical Tensioning Arrangement Fig 7



Angle Station Fig 8