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CHAPTER I

INTRODUCTION

For many years, belt conveyors have been an accepted means of moving materials in continuous flow in the processes of mining, preparation and distribution.

In the last three decades, the ingenuity of the designers and manufacturers of belt conveyors has established these conveyors as the first choice of materials handling equipment for the movement and transportation of materials in large volume, and often under adverse conditions.

1.1 Belt Conveyor History

Belt conveyors have a history almost 160 years old. Their evolution has been a slow process continuing through more than 160 years.

The first reference to the commercial use of belt conveyors in the United States was in the grain industry. Oliver Evans, in his "Millers Guide" published in 1795, described and illustrated a flat conveyor belt for handling grain [1]*.

---

* Numbers in brackets designate references at the end of the Technical report.

Installations similar to this early effort probably were used in many of the grit and flour mills of the early 1800's, although it was customary to convey grains and other light materials in spiral conveyors. Spiral conveyors were more economical in handling small amounts over short distances.

As grain elevators increased in size and scope, they created a demand for continuous conveyors of higher capacity. Belt conveyors answered these requirements and belt conveyor technology was geared to the demands of grain elevator design.

In 1876, W.B. Reaney designed a completely new type of grain elevator (Canton No. 1) for the Northern Central Railroad at Baltimore [2]. This elevator was an important step in the history of belt conveyors in that it introduced 30 inch wide conveyor belts to the handling of grain.

The early 1890's saw the beginning of the use of conveyor belts to handle materials heavier than grain. The largest project of the decade was the New Jersey and Pennsylvania Concentrating Company's ore plant at Edison, New Jersey [1]. It had more than fifty belt conveyors, ranging in width from 20 to 30 inches.

During World Wars I and II and in the intermediate period, the development of material handling equipment progressed at a rapid pace.

In the 1940's and 1950's so many outstanding belt conveyor transportation systems had been built that it is pointless to single out any particular one. Suffice it to say that long haul, overland belt conveyors now are commonly accepted as a modern means of bulk materials transportation, strictly competitive with any other up-to-date means of transportation such as trucks or railroads.

1.2 Uses of Belt Conveyors and General Applications

Whenever materials require continuous transportation, belt conveyors supply a reliable means. Belt conveyors provide an economical and practical means of transporting materials over longer distances than possible with other types of conveyor systems. Materials in large plant operations are sometimes carried on belt conveyors over distances of several miles.

The design of the component parts of a belt conveyor and their arrangement is fairly well established practice.

However, the design of a successful loading, discharge and transfer operations, is largely empirical. The most difficult problem encountered by the designer of a system of belt conveyors is the proper design of the transfer points. This design is influenced by a multiplicity of conditions, such as the material characteristics, the speed of the conveyors, the relative direction of the conveyors, and the rate of handling [3].

Fig. 1 illustrates a single primary belt conveyor feeding a final crushing and screening plant from which sized rock is transferred to seven different conveyors. Each of the seven conveyors stockpiles a different size of crushed rock.

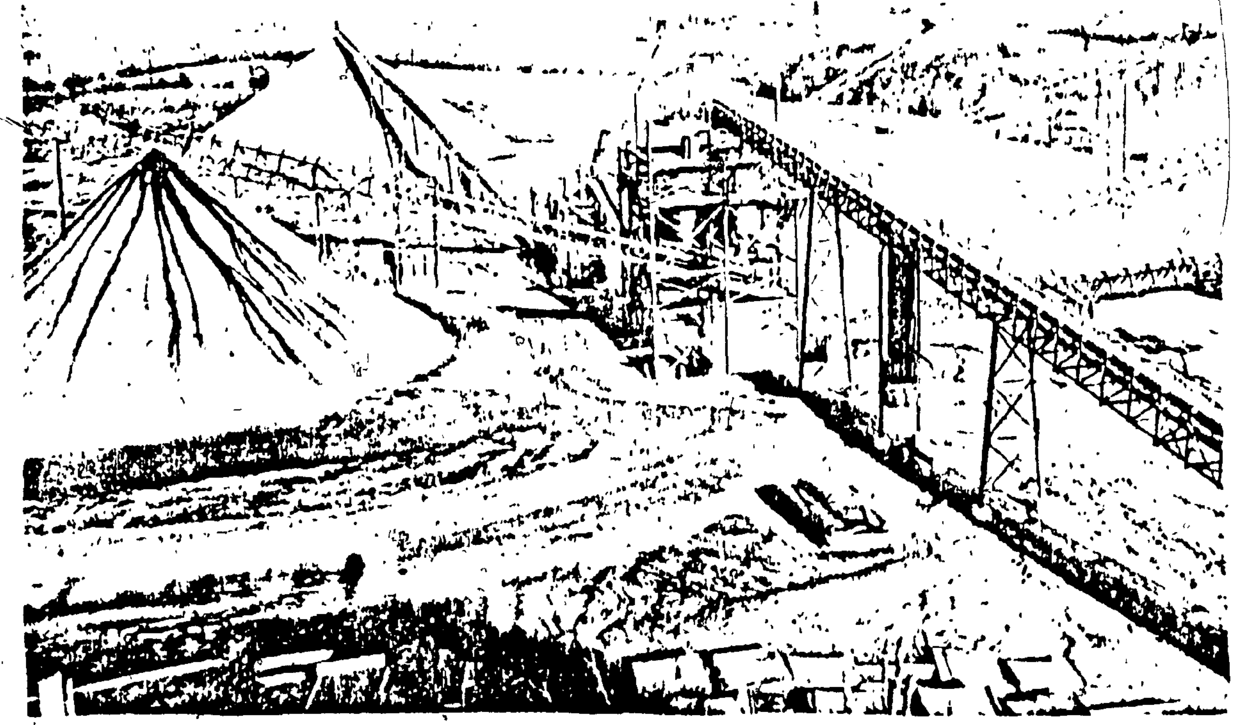


Fig. 1 Material Transfer Within a Conveyor System [1].

1.3 Typical Belt Conveyor Arrangements.

A belt conveyor is an arrangement of mechanical components which support and propel a conveyor belt, which in turn carries the material to be conveyed. The following schematic diagram, Fig. 2, shows a typical horizontal conveyor , and indicates the five principal components which may be defined as (i) The belt, which forms the moving and supporting surface, on which the conveyed material rides, (ii) The idlers, which form the supports for the carrying and return strands of the belt, (iii) The pulleys, which support and move the belt and control its tension, (iv) The drive, which imparts power to one or more pulleys to move the belt and its load & (v) The structure, which supports and maintains the alignment of the idlers and pulleys, and supports the driving machinery.

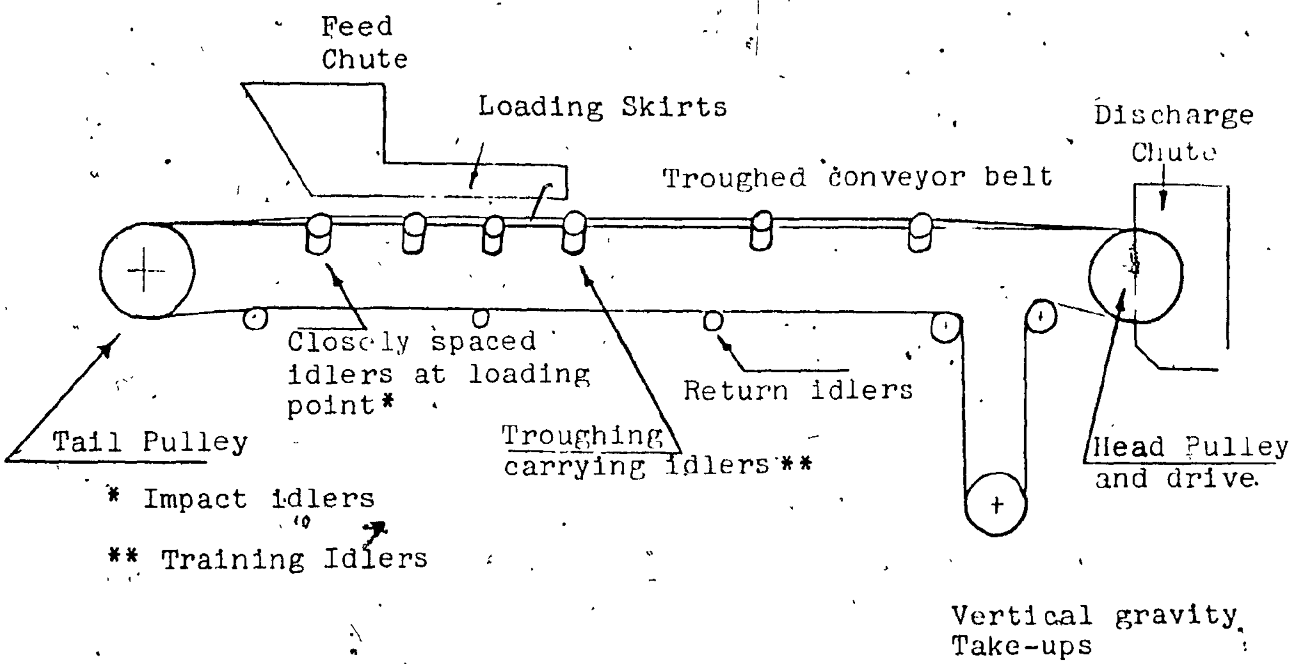


Fig. 2 Typical Horizontal Conveyor.

1.4 Conveyor Profiles and Types of Drive Required

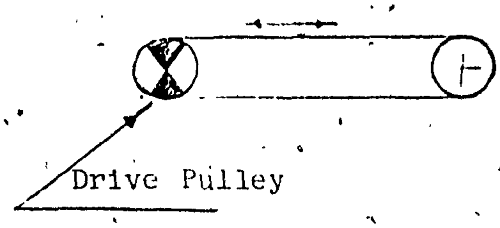
Belt Conveyors may be arranged to have almost an unlimited number of profiles, or paths of travel.

These include a horizontal, inclined, declined, convex or concave vertical curves, or any combination of these.

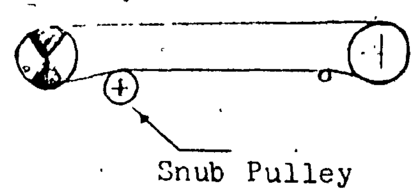
The degree of slope of inclines and declines is limited by the character of the material being conveyed.

Following are some typical belt conveyor profiles and paths, showing the required drives [3, 4 &5].

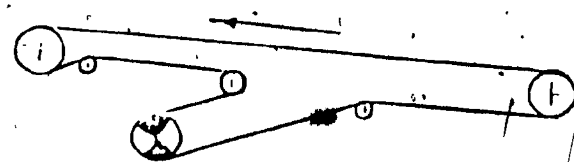
a. Horizontal belt.
Single Drive.



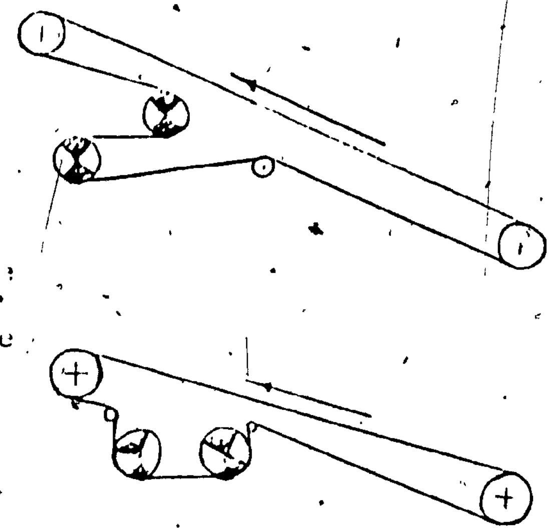
b. Horizontal belt.
Snubbed Single drive.
The pulley to be provided closely to the driving pulley is called " snub pulley ".
So the drive system of this type is called " snubbed single drive ".



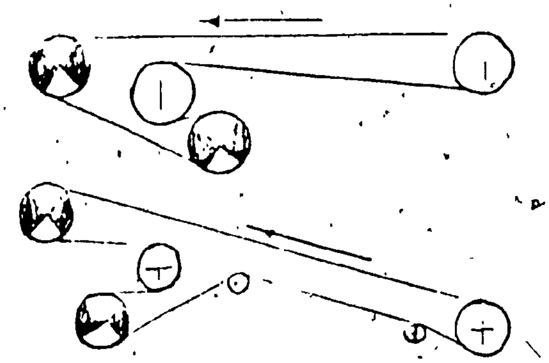
c. Inclined belt conveyor. This system drives only one shaft.



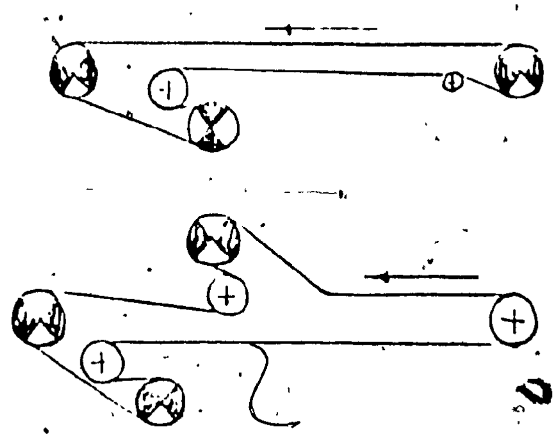
d. Inclined Belt conveyor. Tandem Type Drive: One Shaft is directly driven and another shaft receives the power through the gear, thereby two shafts are driven.



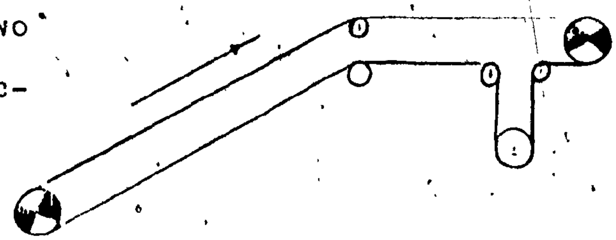
e, f & g. Inclined and horizontal type. Two shafts are driven respectively by a separate motor. This is called Dual Drive.



h & i. Inclined and horizontal belt type. Multi-Drive System. This is the system for driving more than two shafts respectively by a separate motor.



j. Combination of inclined and horizontal path. Two shafts are driven respectively by a separate motor. Dual type.



k. Horizontal and inclined path. Two or more shafts can be driven. Dual or Multidrive system can be used.

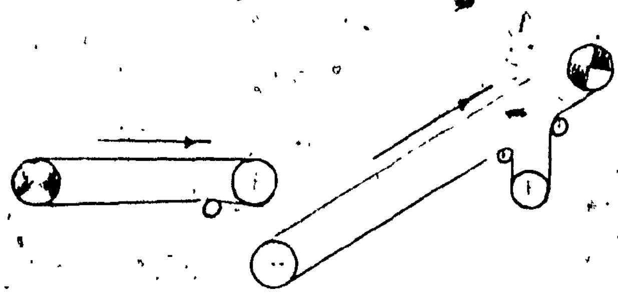


Fig. 3 Belt Conveyor Profiles

CHAPTER 2

CHARACTERISTICS OF MATERIAL HANDLED

The design of a belt conveyor is greatly influenced by the material to be handled. For this purpose it is necessary to have complete knowledge of the characteristics of the material that is to be conveyed.

A few important characteristics are following:

2.1 Angle of Repose

The angle of repose is the angle which the surface of a normal, freely formed pile, makes to the horizontal.

2.2 Angle of Surcharge

The angle of surcharge of a material is the angle to the horizontal which the surface of the material assumes while the material is at rest on a moving conveyor belt. This angle is 5° to 15° less than the angle of repose.

2.3 Flowability of the Material

The flowability of the material as measured by its angle of repose and angle of surcharge determines the cross section of the material load which safely can be carried on a belt. Table I illustrates the flowability and the general characteristics of materials.

Consideration should also be given to the density of the material, its dustiness, wetness, stickiness, abrasiveness, its chemically corrosive action, and its temperature. Some general information concerning these properties of many materials is given in Table 2. Table 3 gives a list of materials with their physical characteristics.

CHAPTER 3

TYPES AND DESIGNS OF CONVEYOR IDLERS

One of the mechanical components of a belt conveyor consists of the idlers which carry and train the belt.

Belt conveyor idlers for transported material are designed to incorporate rolls with 4,5,6 and 7 inch diameters. The rolls are fitted with antifriction bearings and seals, and are mounted on shafts ranging in size from 5/8 inch to 1¼ inch diameter.

Selection of the proper roll diameter and size of bearing and shaft is based on the type of service, operating condition, load carried, and belt speed.

There are two basic types of belt conveyor idlers. These are the carrying idlers, which support the loaded run of the conveyor belt, and the return idlers, which support the empty return run of the conveyor belt.

3.1 Carrying Idlers

Carrying idlers are of two general types. One is for troughed belt and usually consists of three rolls. The two outer rolls are inclined upward, the center roll is horizontal. Metal brackets are attached to a metal frame and hold the three rolls in proper alignement.

The other type is the idler for supporting flat belts. This idler consists of a single horizontal roll positioned between brackets which attaches directly to the conveyor frame.

3.2 Return Idlers

Return idlers usually are horizontal rolls, positioned between brackets which normally are attached to the under size of the support structure on which the carrying idlers are mounted. Figure 4 shows a few different types of idlers.

3.3 Idler Spacing

Idler spacing depends upon (i) the weight of the belt plus the weight of the material load that it carries, and (ii) on the catenary sag of the belt between the idlers. This is true of both troughing and flat belt idlers. The basic equation for the Sag in a catenary may be written [3].

$$\text{Sag} = \frac{W\,S_i^2}{8\,T} \qquad (1)$$

The above equation is also valid for the SI System.

$$W_{mat} = \frac{33.3Q}{V}$$

or $\left[W\ mat = \frac{15.1Q}{V} \right]$ SI System

where: Sag = measured in ft. or (m).

W = weight, $(W_b + W_m)$ lb. per ft or (Kg/M) of belt and material.

S_i = idler spacing, ft. or (M).

T = tension in belt, lb. or (Kg).

Q = capacity in tons per hour.

V = Speed of belt in ft/min or (M/Min).

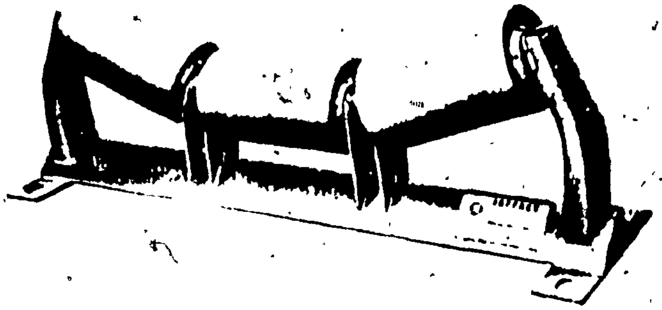
For the best design, and especially on long center troughed belt conveyors, the catenary between idlers should be limited to 3% of the troughing idler spacing.

If the catenary sag of a belt is to be held to 3% of the idler spacing, the above equation may be rewritten as follows:

$$S_i = 0.24 \frac{T}{W} = 0.24 \frac{T}{(W_b + W_m)} \quad (3)$$

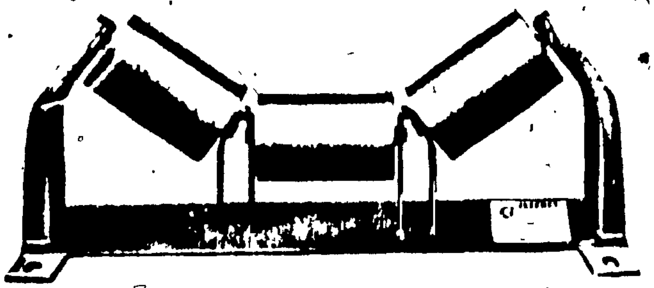
The above equation is also valid for the SI System.

Table 4 suggests the normal troughing idler spacing used in general engineering practice, when the amount of catenary belt sag is not specifically limited.

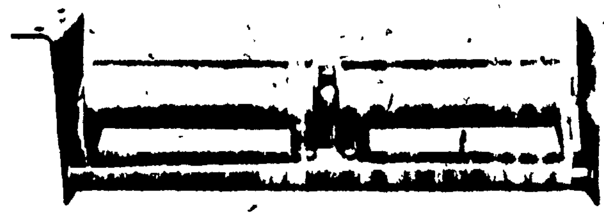


20° troughing belt idler

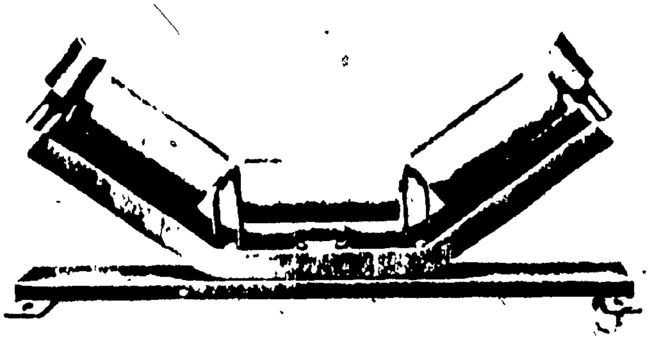
return belt idler



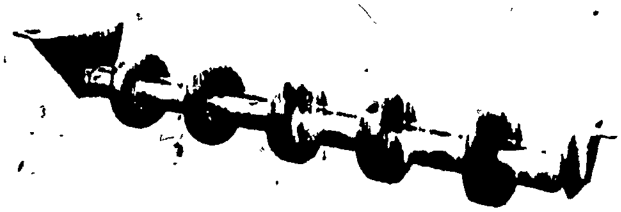
30° troughing belt idler



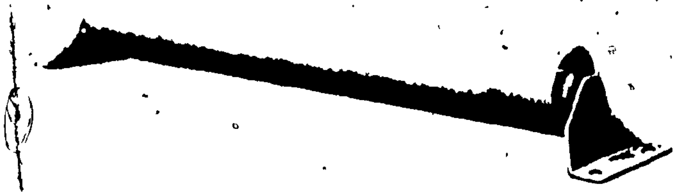
two roll belt return idler



45° troughing belt idler



rubber disc return idler



flat belt idler

rubber disc return idler

Fig. 4. Different Types of Idlers [11].

3.4 Idler Selection

Idler selection depends on (i) the type of service, (ii) the characteristics of the material to be handled, and (iii) the belt speed. Tables 5 and 6 illustrate the service factor A and material characteristics Factor B, respectively. Table 7 shows the estimated average belt weight in lb. per foot length.

By selecting factor A and B from Tables 5 and 6 and multiplying those factors together we get the troughing idler application factor. By multiplying factor A x W_b from Table 7 we get the return idler application factor.

By the use of Figure 5, for known belt speed and the determined troughing idler application factor, the appropriate idler series number for troughing idlers is obtained. Six series idler numbers are covered. Similarly, by the use of Figure 6 for a known belt speed and the determined return idler application factor, the appropriate idler series number for return idlers is obtained.

Finally having the series number we get the roll diameter and size of bearings from Table 8.

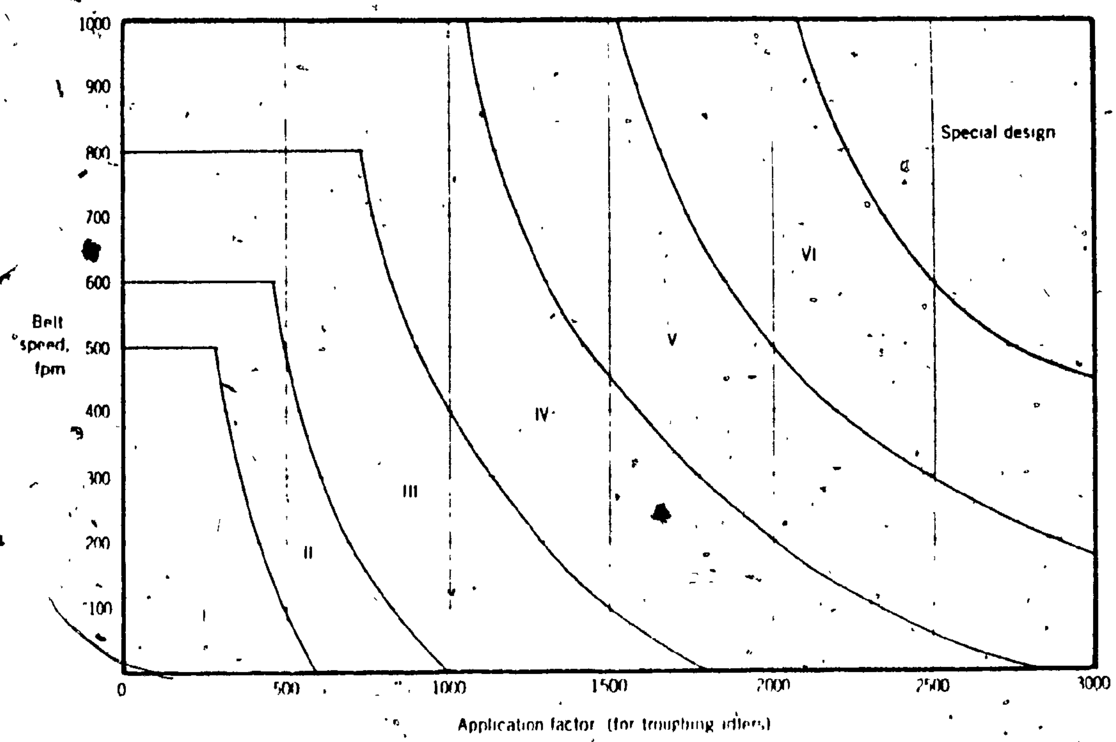


Fig. 5. Troughing Idler Selection Chart [1].

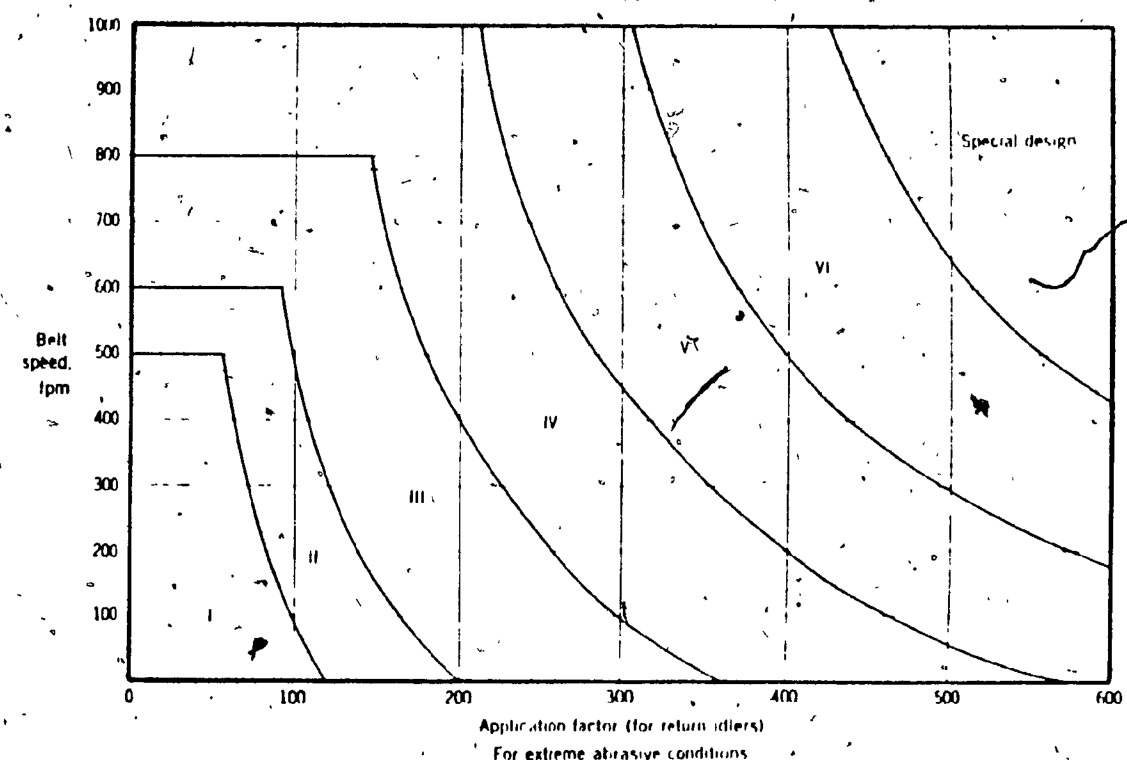


Fig. 6. Return Idler Selection Chart [1].

CHAPTER 4

POWER REQUIREMENTS AND BELT TENSIONS

The power required to drive a belt conveyor is a fundamentally important consideration. It provides the basis for selecting the motor, controls and other drive components as well as for calculating anticipated power consumption. It determines the tensions and strength of belt required and influences belt cost and life.

Before we start deriving any formula the knowledge of some definitions will be helpful, and are defined as follows:

a. Tension

Tension in a belt is a force acting along the length of the belt and tending to elongate it. Belt tension is measured in Pounds or Kilograms.

b. Torque

Torque is the effectiveness of a force to produce rotation about an axis and thus involve the size of the force and its moment arm. The units for torque are pound inches (lb-in) and pound feet (lb-ft) or Kg-cm and Kg-m.

c. Energy and Work

Energy and work are closely related and are expressed in the same units. Work is the product of a force and the distance through which it acts. Energy is the capacity of performing work. The units are the inch pound (in-lb) and foot pound (ft-lb).

d. Power

Power is the rate of doing work or transmitting energy.

4.1 Tension Relationships

Consider a belt in Fig. 7. This belt arrangement illustrates the fundamental tension relations in belt driving.

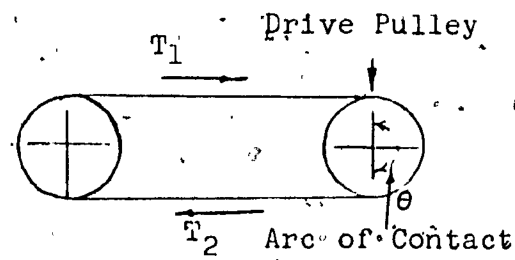


FIG. 7 Tension Relations in Belt Driving

The constant ratio, T_1/T_2 is governed by the coefficient of friction existing between the pulley and the belt, and the extent of the arc of contact between these members. Effective tension is determined as the difference between T_1 and T_2

The slack side belt tension, T_2 and the arc of contact, θ, in radians, necessary to transmit a given force, T_e, from a pulley to a belt is derived from the relationship below [2].

$$\frac{dT}{d\theta} = f \times T \qquad (4)$$

Integrating,

$$f\int_{0}^{\theta} d\,\theta = \int_{T_1}^{T_2} \frac{dT}{T} \qquad (5)$$

$$f\,\theta = \log_e \frac{T_1}{T_2} \qquad (6)$$

$$\frac{T_1}{T_2} = e^{f\theta} \qquad (7)$$

The ratio $\frac{T_2}{T_e}$ is called wrap factor = C_w (8)

Table 9 shows some values of wrap factor C_w.

Then:

$$\frac{T_1}{T_2} = \frac{1+C_w}{C_w} = \frac{1}{(e^{f\theta} - 1)} \qquad (9)$$

where: T_1 = the tight side tension at pulleys lb or (Kg).

T_2 = the slack side tension at pulley, lb or (Kg).

T_e = the difference between T_1 and T_2, lb or (Kg).

f = coefficient of friction between pulley surface and the belt; 0.25 bare, 0.35 lagged.

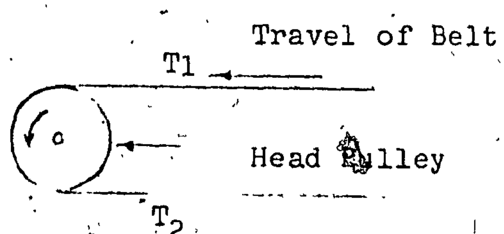
θ = the angle of wrap of belt around the pulley, in radians.

C_W = wrap factor.

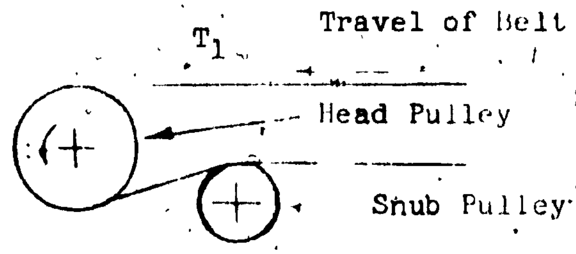
e = the base of Naperian Logarithm.

The wrap angle can be varied:

a. from 180^o to 180^o then the type of the drive is called single pulley.



b. from 180° to 240° , snubbed pulley.



c. from 360° to 480°, Dual drive.

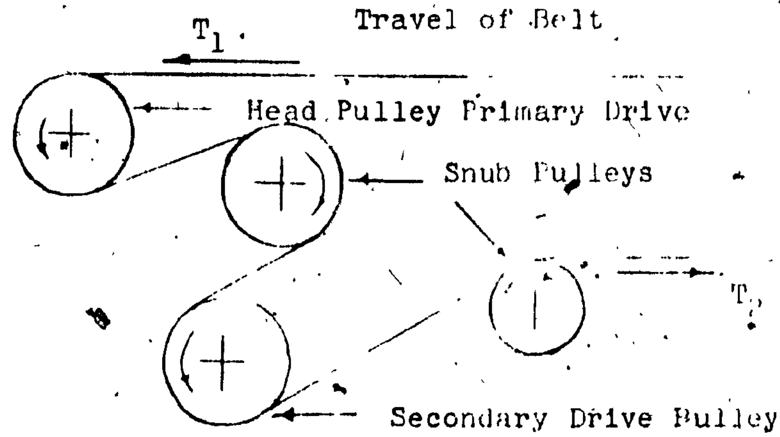


Fig. 8 Types of Drive

Before the horsepower required to operate a belt conveyor is calculated, it is advantageous to consider the belt tensions in belt conveyors of various profiles.

4.2. Conveyor with Head Pulley Drive, Horizontal and Elevating.

[1 , 5 & 6]

a. For an inclined conveyor see fig. 9

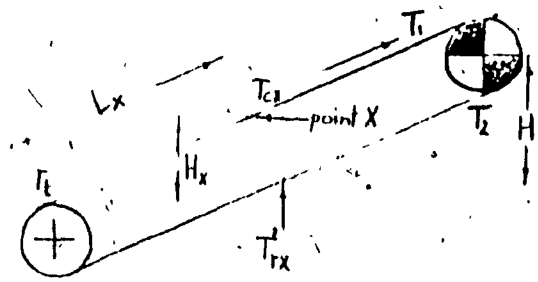


Fig. 9 Inclined conveyor with head pulley drive.

b. For a conveyor with concave vertical curve see fig. 10

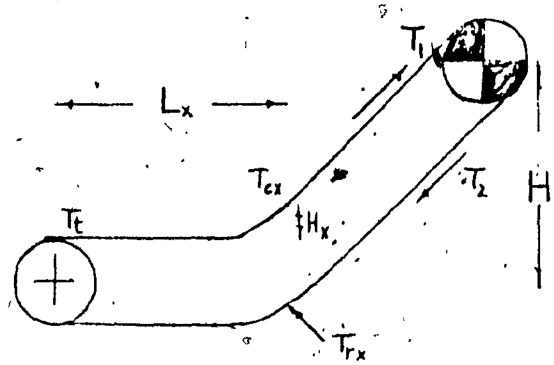


Fig. 10 Horizontal belt conveyor with concave vertical curve.

c. For a conveyor with convex vertical curve see fig. 11

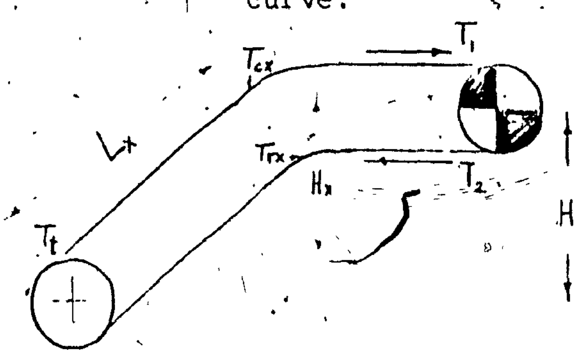


Fig. 11 Horizontal belt conveyor with convex vertical curve

FORMULAE

$Te = T_1 - T_2$ (10)

$T_2 = C_w Te$ or $T_2 = T_t + T_b - T_f$ (11)

where: $T_b = HW_b$ (12)

$T_f = 0.015 L w_h K_t$ (13)

$T_t = T_{min}$, $T_1 = T_{max}$ (14)

Belt tension at point x:

$T_{cx} = T_t + T_{wcx} + T_{fcx}$ (15)

$T_{rx} = T_t + T_{wrx} - T_{frx}$ (16)

where: T_e = Effective Tension ($T_1 - T_2$), in lb or (kg).

T_1 = The tight side tension at pulley, lb or (kg).

T_2 = The slack side tension at pulley, lb or (kg).

T_t = T_{min} = belt tension, lb or (kg), at tail pulley.

T_b = belt tension due to net height and the weight of the belt.

W_b = weight of belt, in lb./ft or (kg/m).

H = net change in elevation in ft or (m).

T_f = return belt friction over the return idlers.

T_{cx} = belt tension, lb . or (kg) at point x on the carrying run.

T_{rx} = belt tension lb . or (kg) at tail pulley.

T_{wcx} = tension, lb . or (kg) at point x on the carrying run resulting from the weight of belt and material carried.

T_{fcx} = tension, lb . or (kg), at point x on the carrying run, resulting from friction.

T_{wrx} = tension, lb . or (kg) at point x on the return run resulting from the weight of empty belt.

T_{frx} = tension, lb . or (kg) at point x on the return run resulting from friction.

H_x = vertical distance, ft. or m, from tail pulley to point x.

W_m = weight of material lb ./ft or (kg/m).

Also:

$$T_{wcx} = H_x (W_b + W_m) \quad (17)$$

$$T_{wrx} = H_x W_m . \quad (18)$$

$$T_{frx} = 0.015\ L_x W_b K_t \ (\text{above } 32^oF\ K_t = 1) \quad (19)$$

or:

$$\left[T_{frx} = 0.015\ L_x W_b K_t \ (\text{above } 0^o C\ K_t = 1) \right] \quad \text{SI System}$$

$$T_{fcx} = L_x \left[K_t (K_x + K_y \times W_b) \right] + L_x K_y W_m \quad (20)$$

K_x and K_y are frictional factors for the horizontal and inclined portion of the belt respectively. Tables 10 and 11. give the values of these factors.

$$\therefore\ T_{ex} = T_{wrx} + T_{frx} + T_{fcx} = H_x W_m + 0.015\ L_x W_b K_t + L_x \left[K_t \left(K_x + K_y W_b \right) \right] + L_x K_y W_m \qquad (21)$$

when $X = L$

$$T_{ef} = HW_m + LK_y W_m + L\left[K_t \left(K_x + K_y W_b + 0.015\ W_b \right) \right] \qquad (22)$$

where: L = length of conveyor.

The same formulae apply for the declined type of conveyor except that the formulae (15) and (16) in this case become:

$$T_{cx} = T_1 - T_{wcx} + T_{fcx} \qquad (23)$$

$$T_{rx} = T_2 - T_{wrx} - T_{frx} \qquad (24)$$

4.3 <u>Power Required</u>

The power required to operate a belt conveyor is determined by three factors.

a. the movement of the conveyor parts.

b. the horizontal movement of the material to be handled.

c. the lifting or lowering of the material. The power required to move the belt conveyor parts and to transport material, usually called the HP of friction.

4.3.1 Calculation of HP for Empty Conveyor [7]:

$$HP = \frac{F(1.07L+50)\times(.03CV)}{1000} \qquad (25)$$

or: $$\left[HP = \frac{F\times(3.51\times L+50)\times(0.066\times C\times V)}{1000} \right]^{**}$$ SI Sytem

where: F = coefficient of friction for anti-friction for idlers.

V = speed of conveyor in fpm or (m/min).

L = length of conveyor in ft, (m).

idlers: F = .03 for general use

F = 0.025 for well maintained units under ideal conditions [3].

C = Weight of moving parts per foot or (m), of center distance. (See Table 11).

Based on the following formula for calculating "C" Table 12 is constructed [8].

$$C = 2W_b + \frac{W_{cr}}{S_{ic}} + \frac{W_{rr}}{S_{ir}} \qquad (26)$$

where:

W_b = weight of belt lb /ft or (Kr/m).

** Horsepower has been considered the same for both systems.

W_{cr} = Wt. of rotating parts of carrying idlers lb . or (kg).
(See table 13).

W_{rr} = Wt. of rotating parts of return idlers.
(See table 13).

S_{ic} = Average spacing of carrying idlers in feet or (m).

S_{ir} = Average spacing of return idlers in feet or (m).

4.3.2. HP Required to Convey Material Horizontally [3].

$$HP = \frac{F(1.07L + 50)\ Q}{1000} \qquad (27)$$

or: $$\left[HP = \frac{F(3.51L + 50)Q}{1000} \right] \quad \text{SI System}$$

where:
Q = capacity in tons per hour.
L = length of conveyor in ft or (m).
F = Coefficient of friction for anti-friction.
(same as previous).

4.3.3. HP Required to Elevate Material

$$HP = \frac{QH}{1000} \qquad (28)$$

or:
$$\left[HP = \frac{3.281 \times QH}{1000} \right] \quad \text{SI System}$$

where:
Q = capacity in tons per hour.
H = vertical ft. or (m) through which material is raised. For lowering or decline conveyor this

HP is regenerative and should be deducted.

By combining the previous equations the total horsepower required is.

a. For horizontal conveyors:

$$HP = \frac{F\ (1.07L+50)\times(Q+0.03CV)}{1000} \qquad (29)$$

or: $$\left[HP = \frac{F(3.51L+50)\times(Q+0.066CV)}{1000}\right] \text{ SI System}$$

b. For inclined conveyors:

$$HP = \frac{F(1.07L+50)\times(Q+0.03CV)+QH}{1000} \qquad (30)$$

or: $$\left[HP = \frac{F(3.51L+50)\times(Q+0.066CV)+3.281\times QH}{1000}\right] \text{ SI System}$$

c. For declined conveyors:

$$HP = \frac{F(1.07L+50)\times(Q+0.03CV) - QH}{1000} \qquad (31)$$

or: $$\left[HP = \frac{F(3.51L+50)\times(Q+0.066CV)-3.281QH}{1000}\right] \text{ SI System}$$

The relationship between the horsepower and effective belt tension is.

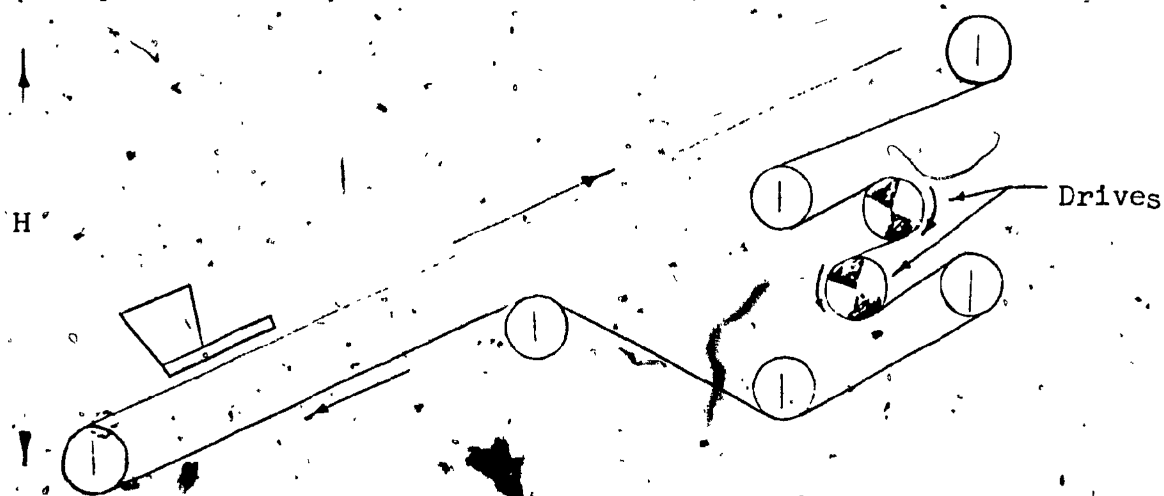
$$T_e = \frac{HP\times 33000}{V} \qquad (32)$$

or: $$\left[T_e = \frac{HP\times 4562.4}{V}\right] \qquad \text{SI System}$$

The following is a technical example of the calculations required to find the tensions and the horsepower for an inclined belt conveyor.

4.4 Example of Belt Tension Calculations

Determine effective tension, T_e, slack-side tension T_2, T_1, T_t (tail tension), Belt and motor horsepower requirements of the following Belt conveyor profile.



Given:

Weight of Belt W_b = 16.6 lb /ft.

Length of conveyor L = 2400 ft.

Speed V = 500 fpm.

Lift H = 75 ft.

Capacity Q = 3400 tph.

Spacing S_1 = 3.0 ft.

Ambient temp.: 60° F.

Belt width : 48 inches.

Material: iron ore at 200 lb / ft^3.

Drive: lagged head pulley or dual drive.

Arc of contact: 240° or 330° depending on which drive is to be used.

Troughing Idlers: Class V, 6 inch diam, 1¼ inch shafts 20° angle.

Return Idlers: Class IV, 6 inch diam. ¾ inch shafts 10 ft spacing.

Solution:

From Table 9 we get drive factor $C_w = 0.30$ or 0.11 for Dual drive.

From Chapter 3 equation (2) gives $W_m = \frac{33.3Q}{V} = \frac{33.3 \times 3400}{500} =$

$= 226.4$ lb /ft.

Temp. $60^{\circ} > 32^{\circ}F \therefore K_t = 1.0$

Equation (22) gives:

$$T_e = HW_m + LK_yW_m + L\left[K_t(K_x + K_yW_b + 0.015\,W_b)\right]$$

$W_b + W_m = 16.6 + 226.4 = 243$ lb ./ft

From Table 10 and ~~11~~ we get:

$K_x = 0.88$ and $K_y = 0.016$

$$\therefore T_e = 75 \times 226.4 + 2400 \times 0.016 \times 226.4 + 2400\left[1(.88 + .016 \times 16.6 + 0.015 \times 16.6)\right] = 29019 \text{ lb}.$$

Slack side tension: $T_2 = T_e C_w = 29019 \times 0.3 = 8706$ lb .

(pulley drive at 240°).

Dual Drive: 380° $C_w = 0.11$

$T_2 = T_e C_w = 29019 \times 0.11 = 3192$ lb .

$T_t = T_{min}$ at tail $= T_2 - T_b + T_f = 3192 - HW_b + 0.015\ LW_b K_t$

$T_{min} = 3192 - 75 \times 16.6 + 0.015 \times 2400 \times 16.6 \times 1 = 2544$ lb .

$T_{max} = T_e + T_2 = 29019 + 2544 = 31563$ lb .

By using equation (32): $T_e = \frac{HP \times 33000}{V}$

or: $HP = \frac{T_e V}{33000} = \frac{29019 \times 500}{33000} = 440$

Add 5% for speed loss = 22 HP

Therefore horsepower required = 440+22 = 462

Rated Belt tension $= \frac{T_{max}}{B.Width} = \frac{31563}{48} =$ 658 lb . per inch of belt width

By proceeding with the same approach we can find the belt tensions at any point of the belt.

CHAPTER 5

BELT SELECTION

One of the most important considerations in the design of a belt conveyor is the selection of the belt.

The belt carries the material and transmits the power to move the load. Belts are made in various types of ply or cord constructions, using such materials as synthetic fibers, steel cables, or combinations of these materials. Each belt is capable of a safe maximum tension stress. Proper belt selection requires consideration of the following.

5.1 Belt Carcass

The carcass of a belt provides the longitudinal strength for transmitting the power and the lateral strength for resisting impact and for carrying the load.

The tension rating depends upon the material and construction of the carcass. The belt carcass must, of course, be sufficient to carry the required tension. Table 14 shows the maximum allowable working tension for various belt carcass constructions, and for mechanical and vulcanized splices.

5.2 Troughability

A conveyor belt must be chosen with sufficient transverse flexibility so that it will conform to the general shape of the troughing idlers. The following formula shows the number of plies required in a conveyor belt [9].

$$N = \frac{T_1}{b \cdot m} \qquad (33)$$

where:

N = number of plies.

T = maximum tension, lb. or (kg).

b = belt width in inches or (cm).

m = maximum allowable unit tension, lb . or (kg) per ply per inch, or per ply per cm of belt width.

5.3 Belt Stretch

Change in belt length due to climatic conditions is usually negligible, but the stretch due to tension is important in determining the amount of travel required for the takeup. Table 15 shows the recommended travel of takeups for belts at operating tensions of 75% and 100% of rated tension of belt.

5.4. Example of Rated Belt Tension Calculation

Let us consider a belt conveyor with a belt width of 30" and calculated maximum horsepower of 30 HP. The required belt speed is 245 FPM.

$$T_e = \frac{HP \times 33000}{245} = \frac{30 \times 33000}{245} = 4040 \text{ lb.}$$

Wrap angle: 210°

Lagged Drive Pulley

From Table 9 for a wrap angle 210° and lagged drive pulley we get: $C_w = .38$

Using equations (11) and (10) we get:

$T_2 = C_w T_e = 4040 \times 0.388 = 1535$ lb .

$T_1 = T_{max} = T_e + T_2 = 4040 + 1535 = 5575$ lb .

Therefore: rated belt tension $= \frac{5575}{30} = 186$ lb /inch of width.

CHAPTER 6

CONVEYOR LOADING AND DISCHARGE

6.1 Conveyor Loading

The successful operation of a belt conveyor requires: first, that the conveyor belt be loaded properly; second, that the material carried by the belt be discharged properly. These two requirements are very important and must be given most careful consideration.

The design of chutes and other loading equipment is influenced by such conditions as the capacity, size and characteristics of material handled, speed and inclination of belt and whether it is loaded at one or several places.

Some of these design considerations are illustrated schematically in Figures 12 and 13.

Some necessary requirements for the loading of a belt conveyor are the following.

a. To load the material on belt at a uniform rate.

b. To load the material on the belt centrally.

c. To reduce the impact of material falling on belt.

d. To deliver material in the direction of belt travel.

e. To deliver material to belt at a velocity as near the speed of the belt as possible.

f. To maintain a minimum angle of inclination of belt at loading point.

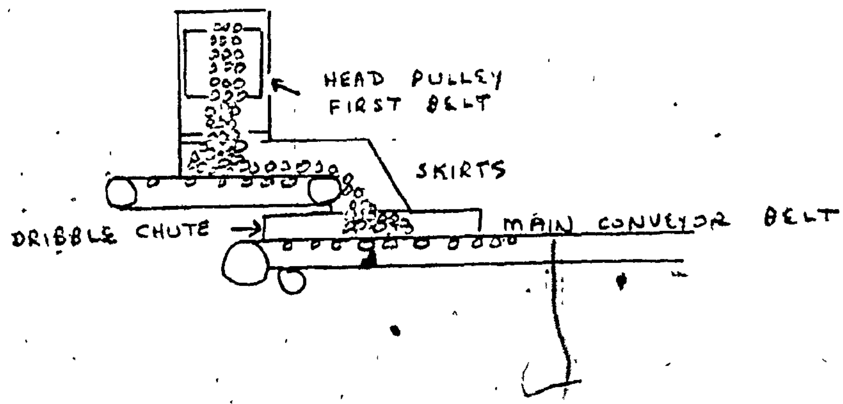


Fig. 12 Arrangement of Transfer Belt Conveyor [10].

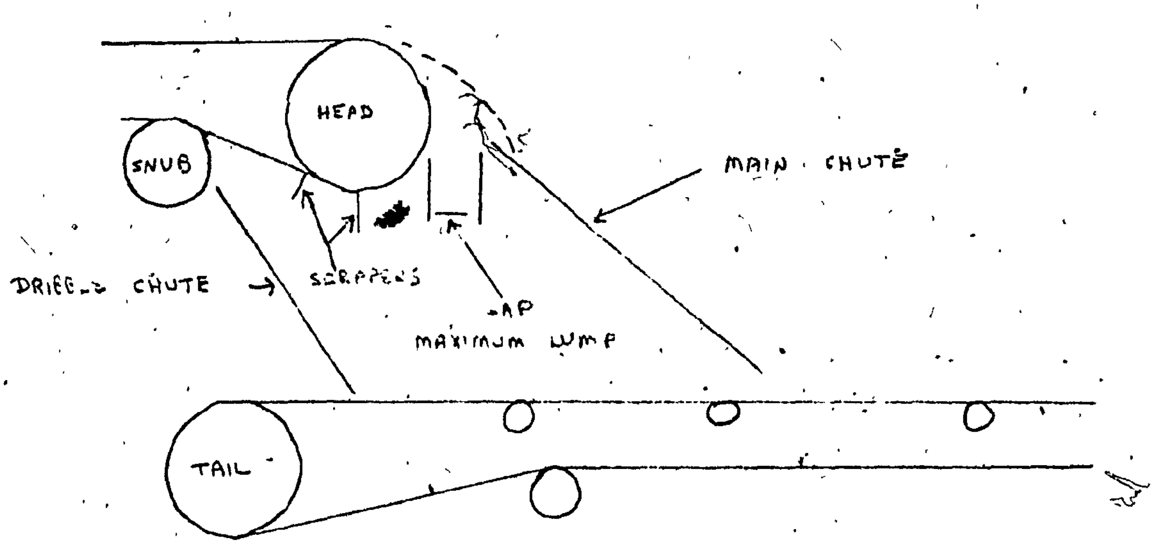


Fig. 13 Chute Profile for Normal Belt Transfer [11].

6.1.1 Loading Chutes and Skirtboards

Loading chutes and skirtboards can seriously damage conveyor belts if not properly designed and installed. Therefore, their design should be given careful consideration. Chutes and skirtboards should be fastened securely to position them accurately with respect to the belt. The width of a loading chute should be no greater than two-thirds the width of the receiving belt. The skirtboards usually are an extension of the sides of the loading chute and extended parallel to one another for some distance along the conveyor belt. The skirtboards and chutes normally are made of metal, although wood sometimes is used.

Figure 14 shows a typical application of skirtboard on troughed belt.

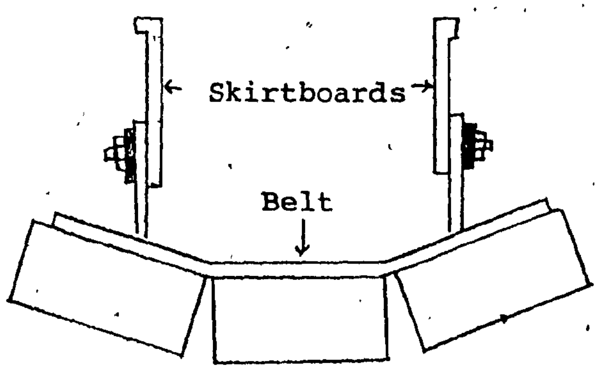


Figure 14 Schematic Diagram of Skirtboard

6.2. Discharge and Calculation of Trajectories

Materials may be discharged from belt conveyors to meet a wide variety of requirements. The discharge locations may be confined to one or more specific points or the material may be distributed along as much of the length of conveyor as desired. The simplest discharge from a conveyor belt is to let the material pass over an end pulley and fall into a pile. By adding a suitable chute, the discharge may be directed as desired, to a pile, or to another conveyor if several specific points of discharge are required, the conveyor belt may be passed over fixed trippers, which will effect the discharge at these points. Figure 16 shows a typical application of discharge of the material to different trippers.

The path of the material leaving a belt is important in determining the location of chutes or receiving hoppers.

The trajectory of the material leaving a belt is determined by the following three relationships.

a. The centrifugal force, acting against gravity, which determines the place where the material leaves the belt.

b. The velocity of the material at the instant it leaves the belt.

c. The force of gravity acting on the material at the instant it leaves the belt and thereafter.

The equations covering the preceding three components affecting the trajectory of material are

$$\text{Centrifugal force} = \frac{WV^2}{gr} \qquad (34)$$

or $\left[\text{centrifugal force} = \frac{WV^2}{gr}\right]$ SI System

$$S = 1/2\ gt^2 \qquad (35)$$

where:

V = belt speed in feet per second or (M/sec)

W = weight of material in lb. per cu. ft. or (Kg/M^3)

g = acceleration due to gravity, 32.2 ft/sec^2 or (9.81 M/sec^2)

R = radius in feet or (m) from the center of rotation to center of load.

T = time in seconds

S = distance material falls when acted upon by gravity, feet or (m)

Centrifugal force acts in a radial direction. Opposed to the action of centrifugal force is the radial component of the material weight on the belt. This component may be calculated by the following equation.

$$\text{Radial Component of Material Weight} = W\cos\phi \quad (36)$$

where:

W = material weight in lb. Same as equation (34).

Ø = angle measured from the vertical, either distance or counterclockwise as indicated in figure 15.

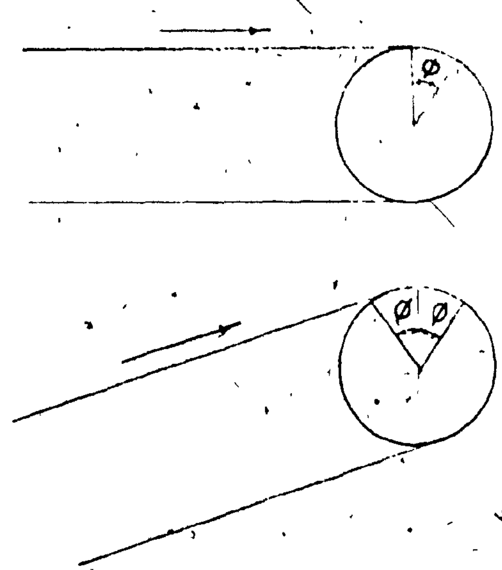


Fig. 15 schematic diagram showing the measurement of the angle for the calculation of radial components.

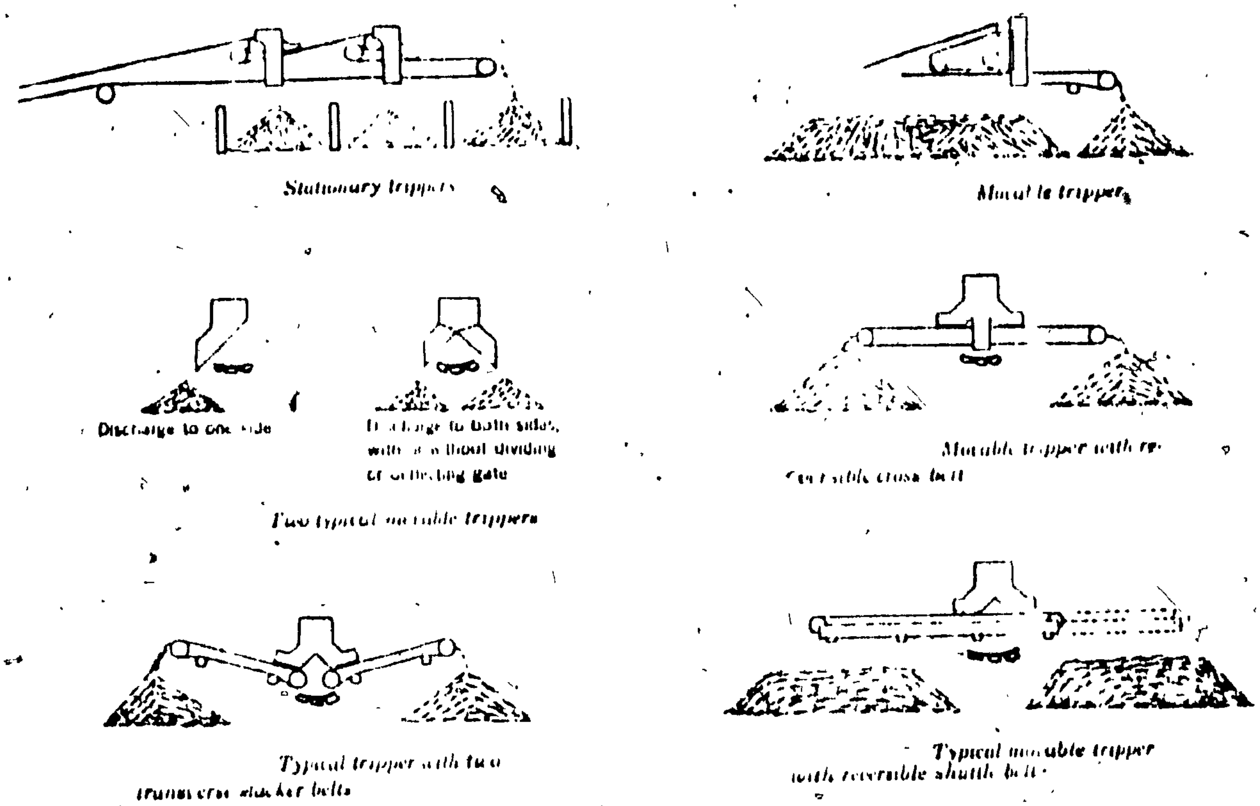


Fig. 16 Different Types of Trippers [1].

Since the radial component of the weight acts in the same path, but in opposite direction to the centrifugal force, the point at which they are equal determines where the material will leave the belt. Thus, we have the following relationship where the material begins to discharge from the belt [2].

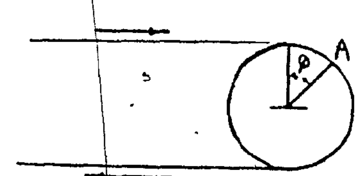
$$\frac{WV^2}{gr} = W\cos\emptyset \quad (37)$$

or:

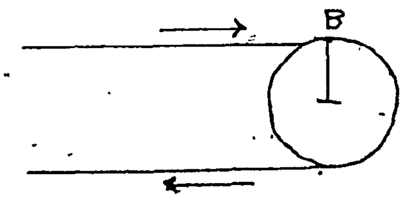
$$\frac{V^2}{gr} = \cos\emptyset \quad (38)$$

When the value of V^2/gr exceeds the cosine of the angle of incline and decline of the approaching conveyor, it indicates that the material will start to leave the belt at the point where the belt becomes tangent to the pulley because the centrifugal force exceeds the radial component of material weight. Following are some general cases showing where discharge begins.

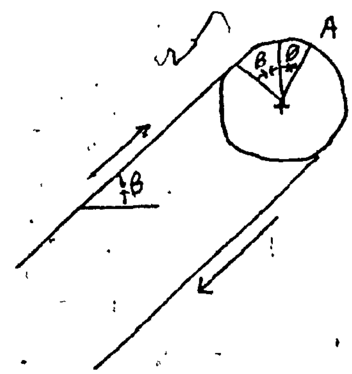
a. If belt speed is such that $\frac{V^2}{gr}$ is less than one, discharge will begin at point "A" where $\frac{V^2}{gr} = \cos\emptyset$



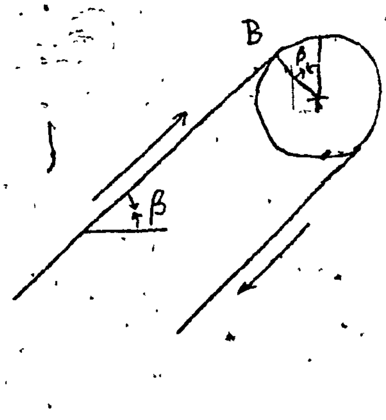
b. If belt speed is such that $\frac{V^2}{gr}$ is greater than one, discharge will begin at "B" or point where belt comes tangent to pulley.



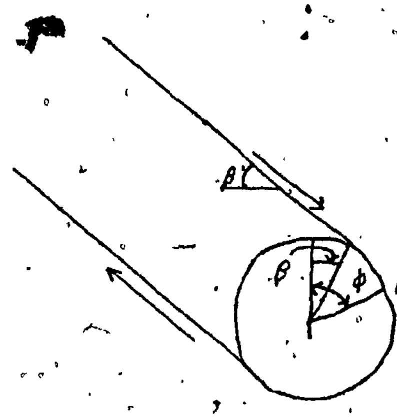
c. If belt speed is such that $\frac{V^2}{gr}$ is less than cosine of angle of incline β, the point of discharge will be at point "A" where $\emptyset$ is an angle whose cosine is $\frac{V^2}{gr}$



d. If belt speed is such that $\frac{V^2}{gr}$ is greater than cosine of angle of incline β, the point of discharge will be at "B" where belt becomes tangent to the pulley.



e. If belt speed is such that $\frac{V^2}{gr}$ is less than the cosine of angle of decline β, the point of discharge will be at "A" where $\frac{V^2}{gr}$ equal cosine $\emptyset$.



f. If belt speed is such that $\frac{V^2}{gr}$ is greater than the cosine of angle of decline β, the point of discharge will be at "B" where belt came tangent to the pulley.

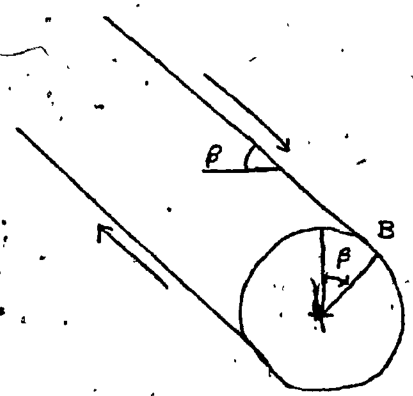


Fig. 17 Different Types of Discharge.

Having determined the point where discharge begins in accord with one of the previously listed cases, a tangent is drawn to the pulley at that point. This tangent represents the path the material would take if it were not acted upon by gravity. The distance "x" which the material would advance along the tangent, equals "vt". However, as the material is also acted upon by gravity it falls a vertical distance "S", equal to $gt^2/2$, using the same intervals of "t" as in calculating values of "x".

The following example will illustrate how to calculate and plot the path of the trajectory.

6.3 Example of Trajectory Calculation

Assume: belt speed = 450 ft/min

Radius: R = 1.5 ft. (pulley radius plus 1/2 load depth).

$$V = \frac{450}{60} = 7.5 \text{ ft/sec}$$

$$\cos(18^\circ) = 0.951$$

$$\frac{V^2}{gr} = \frac{(7.5)^2}{32.2 \times 1.15} = 1.162$$

Since $\frac{V^2}{gr}$ is greater than 0.951 point of discharge (see Case d) will be at "B" where belt comes tangent to pulley.

Using intervals of "t" of 1/20 second, then:

$X = Vt$ and $S = \frac{1}{2} gt^2$

$X_1 = 7.5 \times 1/20 \times 12 = 4.5$ in, $S_1 = \frac{32.2 \times (1/20)^2 \times 12}{2} = 0.484$ in

$X_2 = 7.5 \times 2/20 \times 12 = 9$ in, $S_2 = \frac{32.2 \times (2/20)^2 \times 12}{2} = 1.932$ in

$X_3 = 7.5 \times 3/20 \times 12 = 13.5$ in, $S_3 = \frac{32.2 \times (3/20)^2 \times 12}{2} = 4.35$ in

$X_4 = 7.5 \times 4/20 \times 12 = 18$ in, $S_4 = \frac{32.2 \times (4/20)^2 \times 12}{2} = 7.728$ in

$X_5 = 7.5 \times 5/20 \times 12 = 22.5$ in, $S_5 = \frac{32.2 \times (5/20)^2 \times 12}{2} = 12.07$ in

$X_6 = 7.5 \times 6/20 \times 12 = 27$ in, $S_6 = \frac{32.2 \times (6/20)^2 \times 12}{2} = 17.38$ in

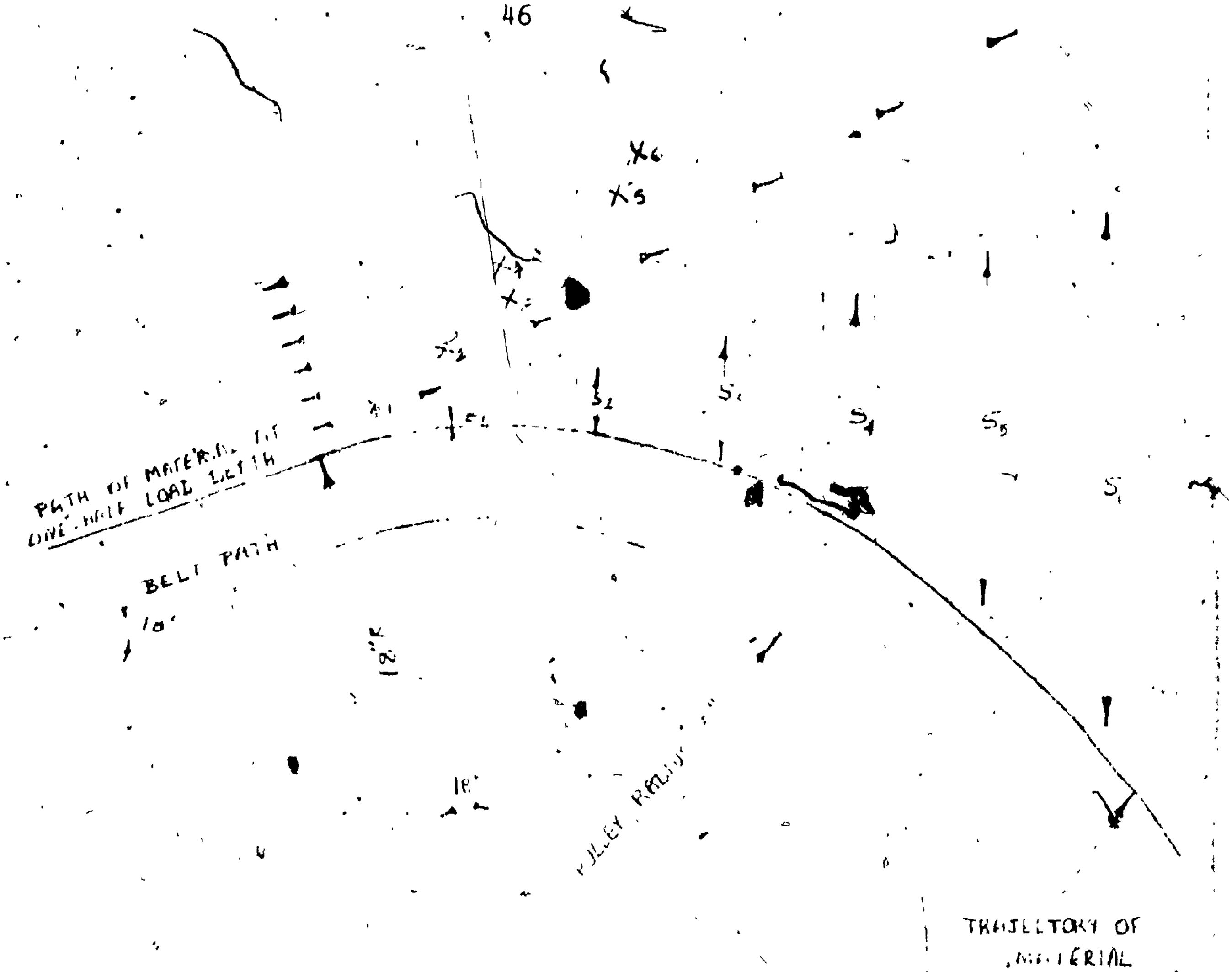


Fig. 18 Plot of Trajectory Path.

CHAPTER 7

PULLEYS AND SHAFTS

7.1 Pulleys

The selection of pulleys is of considerable importance in the design of belt conveyor, since pulleys affect the allowable tension in the belt, the life of the belt, shaft and bearing size and ration of speed reducing equipment.

7.1.1. Pulley Types

The most commonly used conveyor pulley is the standard welded steel pulley. (See Figure 19). These consist of a continuous rim and two end-discs fitted with compression hubs. In some wide face conveyor pulleys, intermediate stiffening discs are welded inside the rim.

7.1.2 Diameter of Pulleys

The diameter of pulley should be large enough to prevent separation of the belt plies and excessive stressing of the outer plies of fabric when the belt bends around the pulleys. Table 16 shows recommended minimum diameter of pulley for various functions based on the rated tension of the belt of the pulley.

For extremely hot materials, pulley diameters somewhat greater than recommended by Table 16 may be helpful in increasing the life of belts, since the larger diameters decreases the stress between the belt plies, and help

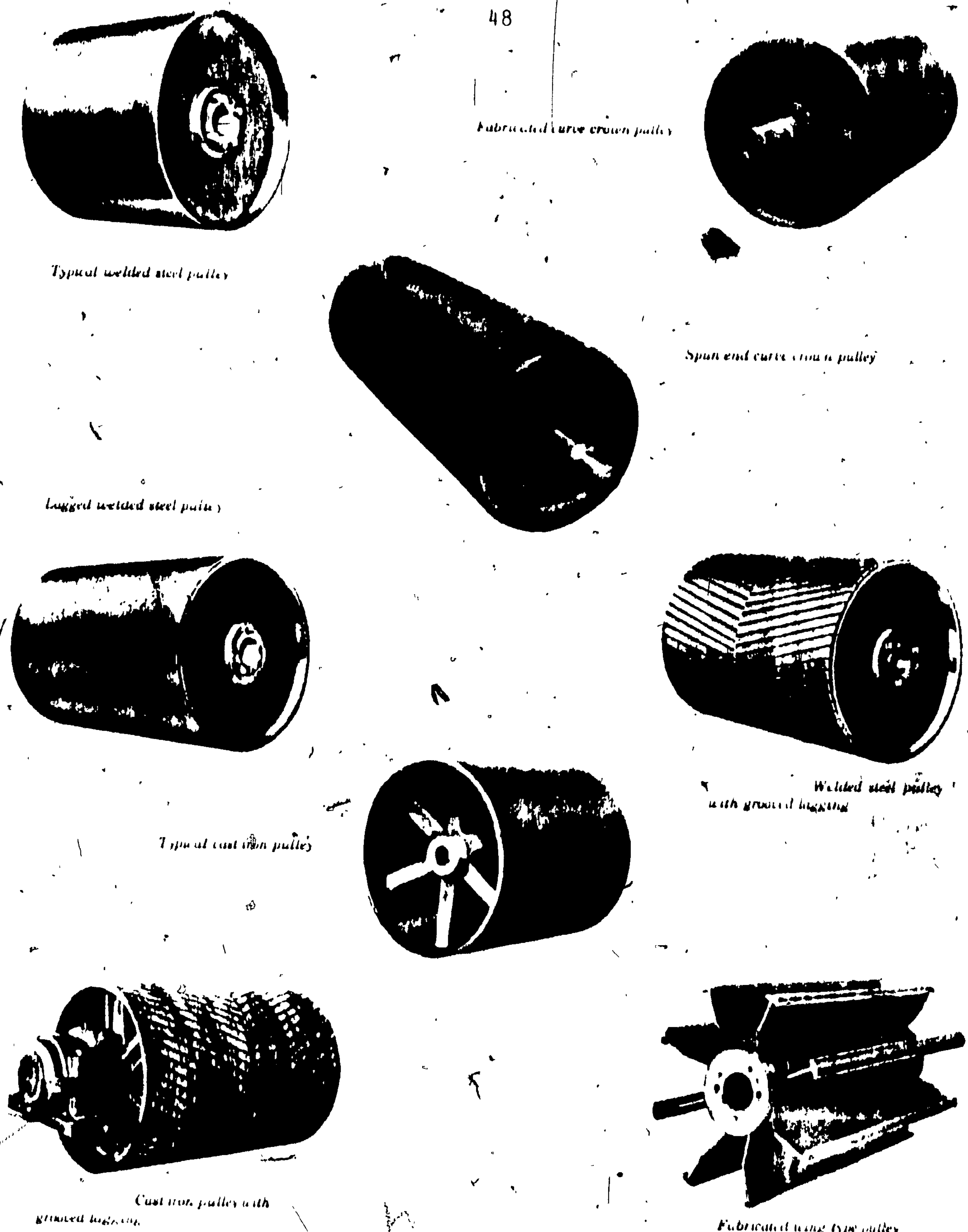


Fig. 19 Types of Pulleys [1].

compensate for the deterioration of the compound which binds the plies together [4].

7.1.3 Width of Pulleys

The width of pulleys should be greater than the width of the belt. Width of standard pulleys exceeds belt width by 2 inches for belts up to 42 inches wide, 3 inches for belts between 42 and 60 inches wide, and 4 inches for belts wider than 60 inches.

7.1.4 Crown Face Pulleys

Crown face pulleys have a definite and desirable centering and guiding effect on the belt. Two closely adjacent pulleys should not both be crowned if it will result in reverse bend in the belt.

Highly stressed pulleys should be straight faced.

7.1.5 Snub Pulleys

Snub pulleys should be used to provide additional wrap around drive pulleys and to bring the return belt in line with the return idlers, so as to relieve return idlers adjacent to pulleys from excessive loading.

7.1.6 Lagged Pulleys

Lagged pulleys are of special advantages for transmitting horsepower to the conveyor belt. They are also desirable for other than drive pulleys as the rubber covering of the pulley rim provides a cushion to protect the surface of the belt as it passed over the pulleys. Lagging also helps make pulleys self cleaning when some materials have a tendency to build up on the pulley surface.

7.1.7 Determination of Actual Resultant Radial Load

The Resultant Radial Load is the vector sum of the belt tensions, pulley weight and weight of the shaft. The force from the weights always acts downward and the force from the belt acts in the path of the belt and away from the pulley. In most cases, a graphical solution as illustrated in Figure 20 is a simple means of obtaining the resultant load.

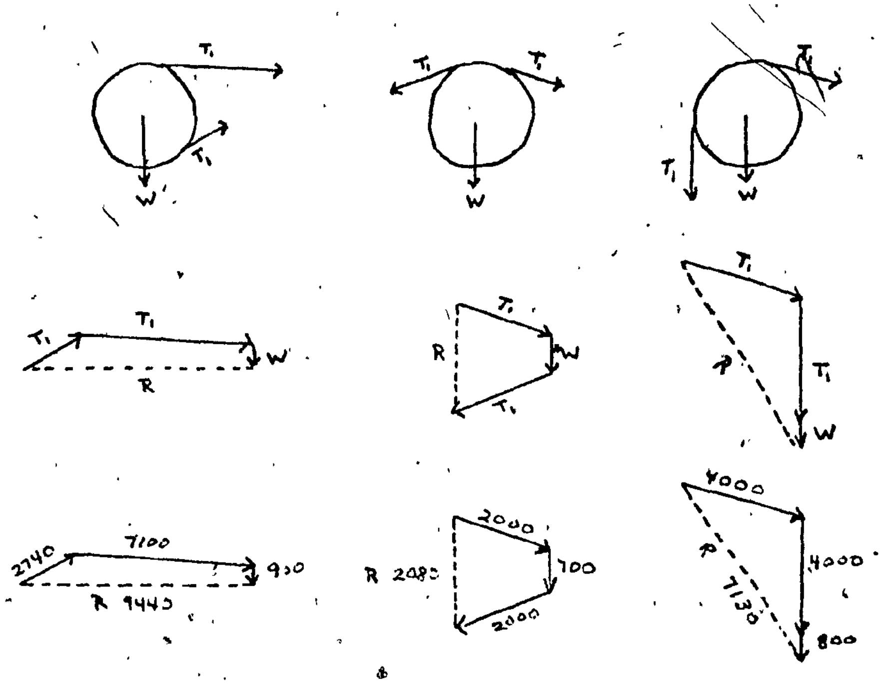


Fig. 20. Graphical Solution for Obtaining Resultant Radial Load.

7.2 Shaft Selection

The selection of suitable shafting to be used with standard welded steel pulleys cannot be established independently of the pulley load rating. The shaft and the pulley must be treated as a composite structural assembly. This is simply the result of the fact that the structural rigidity of the assembly depends both on the shaft and the pulley.

There are two methods of approaching the selection of the shaft.

The first method consists of making a tentative shaft selection based on the chart presented, in Fig. 21.

The second method requires a shaft calculation according to the ASME Code for the design of transmission shafting.

The ASME Code defines an allowable or design shear stress which is the smaller of the two following values [12].

$$\tau_d = 0.30 S_{yt} \quad \text{or:} \quad \tau_d = 0.18 S_{yt}$$

where: τ_d is the maximum permissiable shear stress

S_{yt} is the yield strength

The maximum shear stress in a shaft subjected to both bending and torsion is found by the following formula [12].

$$\tau_d = \frac{16}{\pi d^3} (M^2 + T^2)^{\frac{1}{2}} \qquad (39)$$

or: $$\left[\tau_d = \frac{103.22}{\pi d^3} (M^2 + T^2)^{\frac{1}{2}} \right]$$ SI System

where: τ_d = maximum shear stress, psi (kg/cm^2).

d = diameter of shaft, in or (cm).

M = bending moment, lb_f-in (Kg_f-cm).

T = torsion at moment, lb_f-in (Kg_f-cm).

π = constant (3.14).

In the code the bending moment M and the torsional moment T are multiplied by shock and fatigue factors C_m and C_t, respectively, depending on the conditions of the particular application [12].

thus: $$\tau_d = \frac{16}{\pi d^3} ((C_m M)^2 + (C_t T)^2)^{\frac{1}{2}} \qquad (40)$$

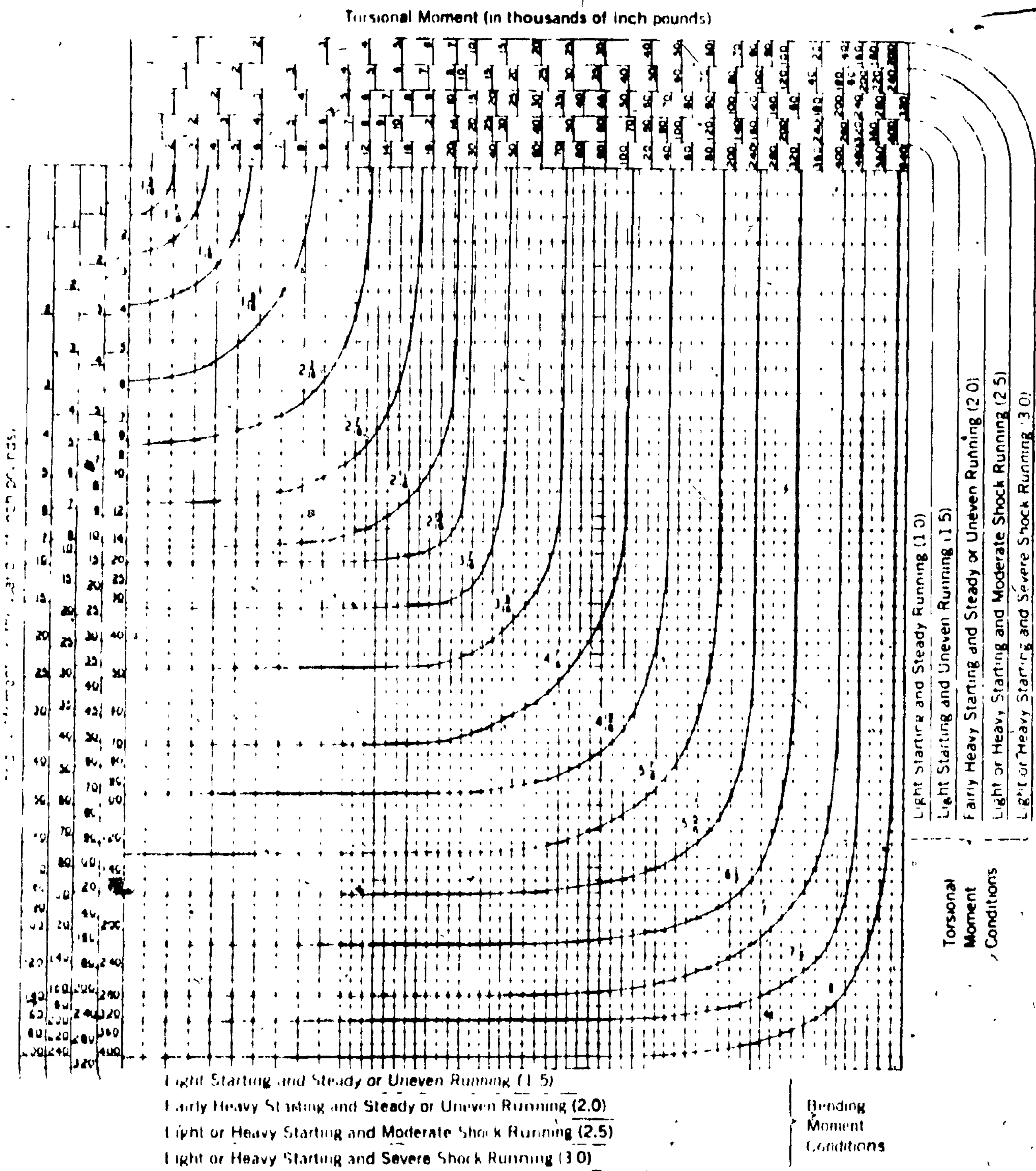
Equation (40) can be solved for the shaft diameter.

$$d = \left\{ \frac{5.1}{\tau_d} \left[(C_m M)^2 + (C_t T)^2 \right]^{\frac{1}{2}} \right\}^{1/3} \qquad (41)$$

or: $$\left[d = \left(\frac{32.9}{\tau_d} ((C_m M)^2 + (C_t T)^2)^{\frac{1}{2}} \right)^{1/3} \right]$$ SI System

In pulley applications C_m and C_t are 1.5 and 1 respectively.

Recommended values of C_m and C_t are listed in Table 17.



Safe Shear Stress	Factor	Safe Shear Stress	Factor	Safe Shear Stress	Factor	Safe Shear Stress	Factor	Safe Shear Stress	Factor
500	2.289	3,000	1.260	5,500	1.029	9,000	0.874	14,000	0.754
1,000	1.817	3,500	1.197	6,000	1.000	10,000	0.843	15,000	0.737
1,500	1.587	4,000	1.145	6,500	0.974	11,000	0.817	16,000	0.721
2,000	1.442	4,500	1.101	7,000	0.950	12,000	0.794	17,000	0.707
2,500	1.339	5,000	1.063	8,000	0.909	13,000	0.773	18,000	0.693

FIGURE [illegible] Standard shafts combined torsion and bending (Based on safe shear stress of 6,000 psi for keyseated shafting) [10].

CHAPTER 8

VERTICAL CURVES

Vertical curves in belt conveyors are used to connect two tangent portions which are on different slopes. They are of two basically different types: concave vertical curves, where the belt is not restrained from lifting off the idlers; and convex vertical curves, where the belt is restrained by the idlers.

8.1 Concave Vertical Curves

This type curve is the most common cause of curve trouble in that failure to put in a correct concave curve is immediately apparent in lifting of the belt.

The most important part of calculating a concave curve is determination of belt tension. This means not simply operating tension, but peak tension resulting from acceleration or braking, or from any probable spasmodic loading combination. It will be noted that the belt is presumed to be empty in the region of the curve and loaded in all other sections, which, by being loaded, increase tension at the curve being determined.

The formula below may be used to obtain the minimum recommended vertical curve radius "R" [4].

$$R = \frac{T_c}{W_b \times \cos\alpha} \qquad (42)$$

or:

$$\left[R = \frac{T_c}{10.76\, W_b \times \cos\alpha} \right] \quad \text{SI System}$$

where:

R = Curvature radius ft. or (m)

T_c = belt tension, lb /ft. or Kg/m

W_b = weight of the belt lb or (kg)

α = transition angle.

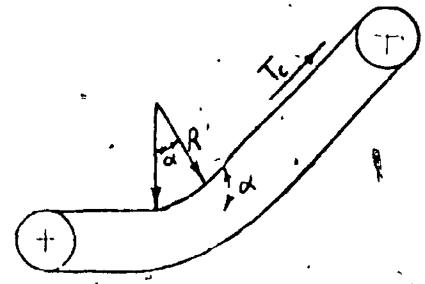


Fig. 22 Concave Vertical Curve.

8.2 Convex Curves

A conveyor belt is said to pass through a convex vertical curve when the center of curvature lies below the belt. In such cases, the gravity forces of belt and of load (if present), and the belt tension itself, presses the belt onto the idlers.

If a convex vertical curve is located where the belt tension is low, the distribution of stress across the belt may result in less than zero tensile stress at the center of the belt. This can produce buckling in the belt and possible spillage of the load.

The following equations are used to determine the minimum radius to prevent the tension at the belt edges from exceeding the belt rated tension [5 & 10]

$$\text{Min } R = \frac{\sin\theta \times b \times E \times P}{54\ (T_r - T_c)} \qquad (43)$$

or: $\left[MinR = \frac{\sin\theta \times b \times E \times P}{54\ (T_r - T_c)} \right]$ SI System

where: R = minimum radius of convex curve, in or (cm).

θ = trough angle.

b = belt width, inches or (cm).

E = belt or carcass modules, lb/in or (kg/cm).

T_r = rated belt tension, lb /in or (kg/cm).

P = Number of plies in the belt.

T_c = calculated belt tension at the curve lb /in or (Kg/cm).

The following equations are used to determine the minimum radius to prevent the belt tensions from dropping below zero and so causing buckling.

$$MinR = \frac{\sin\theta \times b \times E \times P}{54\ (T_c - 25)} \quad (44)$$

or: $\left[MinR = 5.598 \times \frac{\sin\theta \times b \times E \times P}{54\ (5.598 T_c - 25)} \right]$ SI System

When it is difficult to have the radius of curvature as calculated, it is necessary to take such countermeasures as to make the trough angle at the transition point shallow or to adjust the position to be able to mount the carrier roller.

CHAPTER 9

BELT CONVEYOR TAKE-UPS

9.1 Reasons for Using Take-Ups.

The use of takeup devices in belt conveyors is necessary for the following reasons:

a. To maintain sufficient slack side tension, T_2, for the drive to operate the belt.

b. To keep the sag between idlers to a minimum, in order to prevent disturbance of the material as it passes over the idlers.

c. To permit length variation in the belt as it stretches or shrinks.

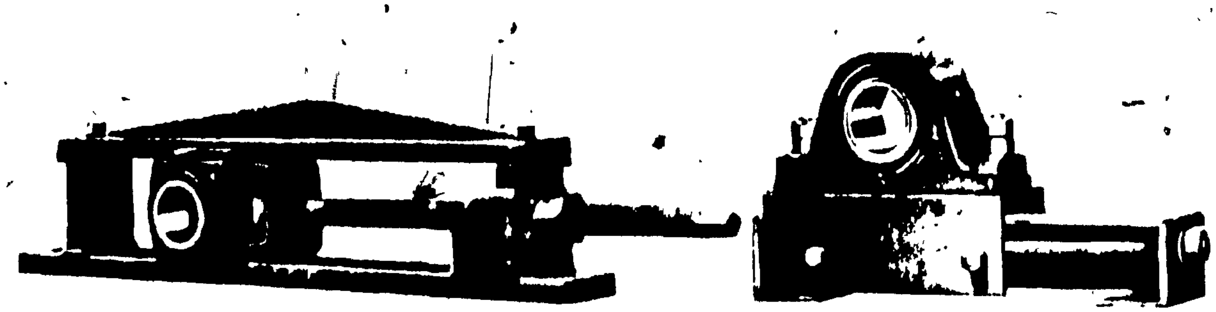
d. With a gravity or automatic type of take-up, some of the starting shock is removed from the belt.

e. When it is possible, to provide for an extra long take-up movement, the additional belting gives the operator a chance to cut out a portion of the belt which may have been damaged by accident. There will probably then be enough belt to make one splice. This sometimes also provides storage space for extra belting, usually shipped, which would ordinarily be cut off and thrown away:

There are two types of take-up in general use, screw or manual and automatic.

9.2 Screw type

The screw type take-up moves the head, tail or take-up pulley and positively fixes the centers. It is used on short centre conveyors and needs using higher stresses in the belt than are are actually essential for operation. At any take-up setting, there must be sufficient tension applied to give the belt a chance to stretch while still maintaining sufficient tension for driving. Figure 23 shows two different types of screw take-ups.



Exposed screw takeup with babbitted bearing

Protected screw takeup with roller bearing pillow block

Fig. 23 Two different types of screw take-ups [1].

9.3 Automatic type

The automatic take-ups are the most desirable type for use on any belt conveyor and are required for good operation on all belt conveyors over 200 ft in length. They can be installed horizontally, vertically, or on an incline. They can be either gravity operated or power operated by hydraulic, electric, or pneumatic means. The most common type of automatic take-up, however, is the gravity take-up.

Shown in Figure 24 is a horizontal automatic gravity take-up at a tail pulley, and a vertical automatic gravity take-up for use near a head pulley.

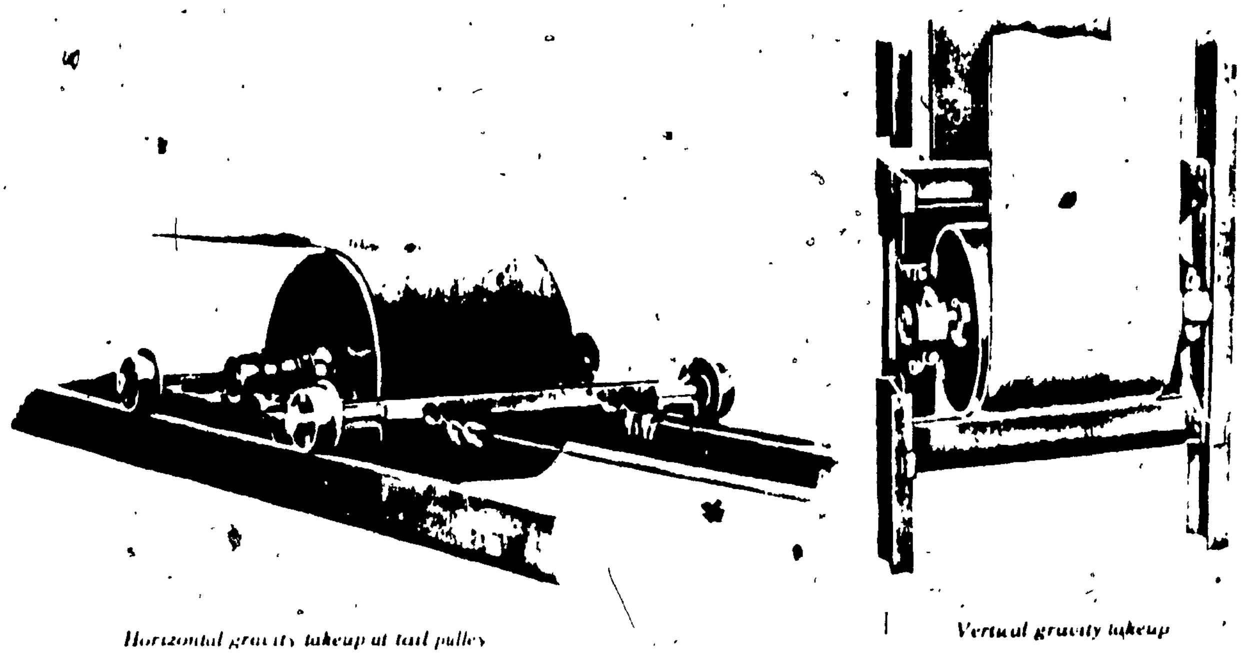


Fig. 24 Two different types of automatic take-ups [1].

9.4 Automatic Take-up Location

Automatic take-ups may be located at any place in the return run of the belt conveyor. The prime consideration being where the automatic take-up will work best in relation to the drive, to keep belt tensions at a minimum. Other considerations, such as available space, maintenance conditions, and the economics of the location, should be taken into account.

Generally, the most inexpensive location for an automatic take-up is at the tail of an inclined conveyor. At this point, no additional pulleys will be involved. On those conveyors inclined at more than 10% slope, the weight of the return belt usually provides enough slack-side tension.

On long horizontal conveyors, and conveyors inclined at less than 5% slope, the automatic take-up can be located near the drive where it will act quickly enough to prevent slippage of the belt on the drive pulley during the acceleration at start up.

9.5 Calculation of Take-up Weight

An automatic gravity take-up must provide a weight or gravity force equal to twice the required belt tension, at the place where this take-up is installed. This weight usually is supplied by a counterweight composed of steel, cast iron, concrete, or some other heavy material equal to the weight required. Some adjustment to the weight force should be provided, as shown in Figures 25 and 26, to meet unforseen operating conditions.

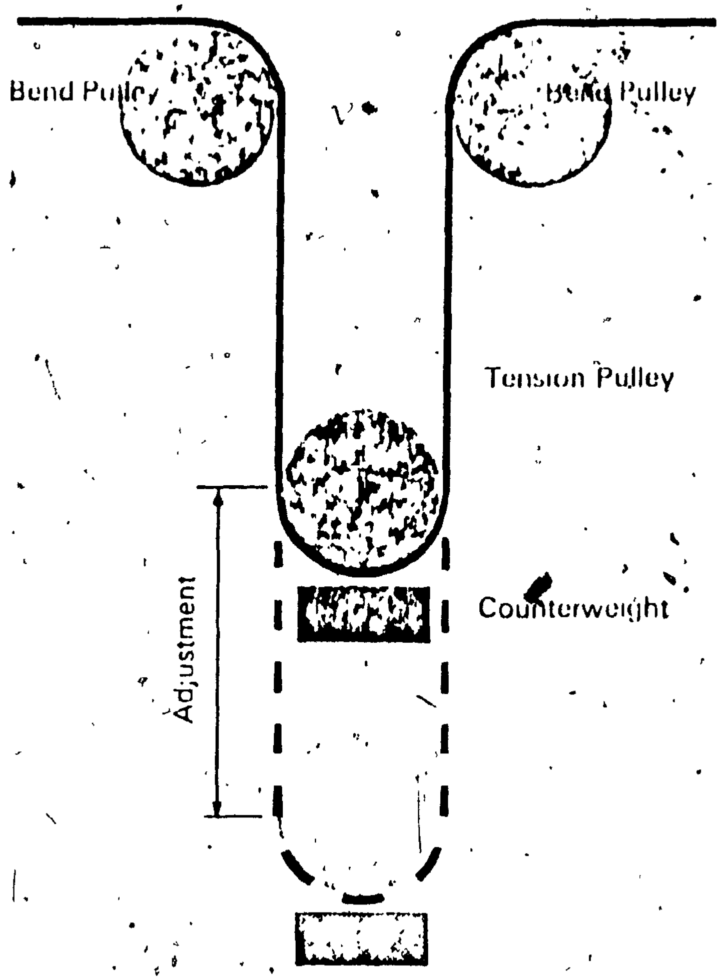


Fig. 25 Schematic Diagram Showing Vertical Gravity Take-up[5].

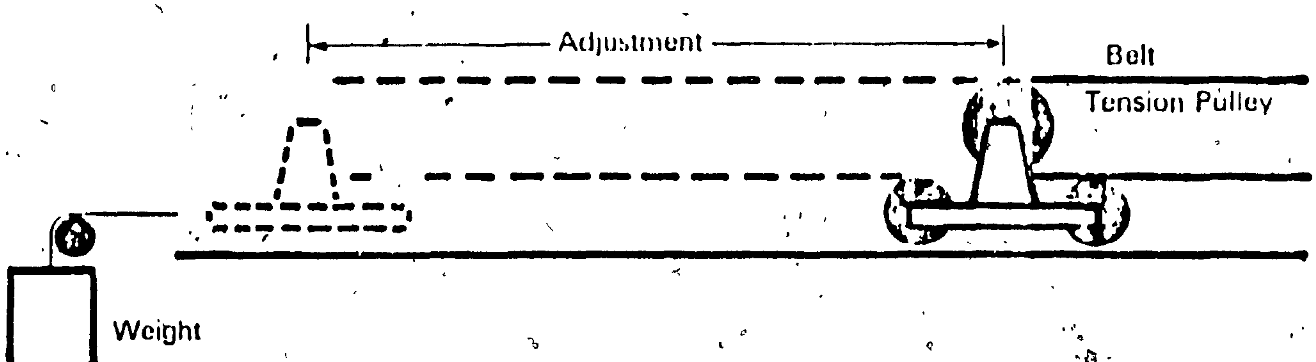


Fig. 26 Schematic Diagram Showing Horizontal Take-up [5].

To calculate the required force of the automatic take-up, or the weight force of a gravity take-up, the following formula can be used [7].

$$W_g = \frac{2T + W_f - W_p}{R} \tag{45}$$

or: $\left[W_g = \frac{2T + W_f - W_p}{R} \right]$ SI System,

where: W_g = required force, lb. or Kg, provided by the take-up. In gravity take-ups, it is the weight force, in lb or (Kg).

T = Belt Tension, lb or (kg), at the point where the take-up is located

W_f = force, lb or (Kg), to overcome friction of the take-up carriage, ropes, sheaves, or other frictional resistance.

W_p = vertical component of the weight force of the take-up carriage, wheels, pulley, shaft, etc. in lb of (kg); where these elements move horizontally, W_p becomes zero.

R = mechanical advantage ratio, if any mechanical advantage is provided.

In a hydraulically or pneumatically operated automatic take-up, the force is calculated as above. As with a gravity automatic take-up, the force should be adjustable to meet unforseen operating conditions. This can be done by varying the hydraulic or pneumatic pressure to meet the actual operating conditions.

CHAPTER 10

CONCLUSIONS

Basically, a conveyor consists of a fabric belt, usually rubber covered, that passes around two cylindrical pulleys located at either end. The top surface of the belt is used to transport materials.

The belt conveyor is an indispensable tool in the field of materials handling. It is the work-horse of the materials handling industry.

Some of the advantages of belt conveyors are that they provide high capacity for low power and deliver uniform volumes of almost any material. They are also low in initial cost and maintenance, yet simple, quiet, reliable and adaptable to many conditions.

The belt conveyor may be arranged to operate in the horizontal plane, or at various angles. The maximum allowable angle will be determined by the type of material being carried and the angle at which it begins to roll or slip along the surface of the belt due to the force of gravity. Most materials cannot be conveyed on angles steeper than 20 degrees. By using an apron conveyor, however, inclines up to 45 degrees may be achieved.

The limiting speed of a belt conveyor is that point at which centrifugal force inhibits the grip of the drive pulley on the belt, or the speed at which air resistance blows the materials from the belt. Suitable belt conveyor speed depends largely upon the characteristics of the material to be conveyed, the capacity desired and the belt tension employed. Powdery or fragile materials, for example, should be conveyed at low speeds, while heavy and sharp-edged materials should be conveyed at moderate speeds.

Very often, special characteristics of the material being handled make the use of belt conveyors impractical. A belt conveyor would be plagued with problems when handling materials at high temperatures (300° F, and over). Belt conveyors would not be practical in dealing with sticky or extremely abrasive or corrosive materials. For such cases other units may be especially useful, as for example a screw or oscillating conveyor.

The limits of belt conveyor design cannot be predicted. The prospects for new developments are great, as improvements in feeders, idlers, belts and pulleys are introduced constantly.

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APPENDIX TABLES

Table 1. Flowability of Materials [1].

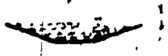
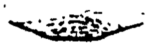
1 Very free flowing	2 Free flowing	3 Average flowing		4 Sluggish.	Profile on flat belt
5 Angle of surcharge	10 Angle of surcharge	20 Angle of surcharge	25 Angle of surcharge	30 Angle of surcharge	Angle of surcharge
					
0 20 Angle of Repose	20 30 Angle of Repose	30 35 Angle of Repose	35 40 Angle of Repose	40 Up Angle of Repose	Other Angles of Repose
MATERIAL CHARACTERISTICS					
Uniform size very small rounded particles either very wet or very dry such as dry silica sand, cement, wet concrete etc.	Rounded, dry polished particles [illegible]	Irregular granular or lumpy materials [illegible] as anthracite coal cotton seed meal clay	[illegible] bituminous coal stone [illegible]	Irregular, stringy, [illegible] interlocking material [illegible] lump [illegible] sand etc.	[illegible]

Table 2. Materials Class Description [1].

	Material Characteristics
Size	Very fine – 100 mesh and under Fine – 1/8 inch and under Granular – Under 1/2 inch Lumpy – containing lumps over 1/2 inch Irregular – stringy, interlocking, mats together
Flowability Angle of Repose	Very free flowing – angle of repose less than 20 degrees Free flowing – angle of repose 20 degrees to 30 degrees Average flowing – angle of repose 30 degrees to 45 degrees Sluggish – angle of repose 45 degrees and over
Abrasiveness	Non-abrasive Abrasive Very abrasive Very sharp – cuts or gouges belt covers
Miscellaneous Characteristics (Sometimes more than one of these characteristics may apply)	Very dusty Aerates and develops fluid characteristics Contains explosive dust Contaminable affecting use or saleability Degradable, affecting use or saleability Gives off harmful fumes or dust Highly corrosive Mildly corrosive Hygroscopic Interlocks or mats Oils or chemical present – may affect rubber products Packs under pressure Very light and fluffy – may be wind swept Elevated temperature

Table 3. Physical Characteristics of Materials [5].

Material	Weight lb/cu. ft	Approximate angle of Repose Degrees
Acid phosphate fertilizer	60	
Alum lump	50-60	27
pulverised	45-50	35
Ammonium Sulphate wet	80	45
dry	70	32
Asbestos shredded	20-25	45-48
Ashes, boiler-house, dry	43	38-45
gas producer, wet	78	62
Bagasse, fresh, moist	75	
dry, loose	50	
Bakelite, powdered	30-40	45
Baking powder	60	40
Barytes, solid	265	
2"-3" lumps	145-160	30
1½"-2" lumps	135-140	30
½" screenings	130-145	30
fines	110-130	35
Basalt, solid	190	
2"-3" lumps	105-110	
1½"-2" lumps	85-105	
½" screenings	90-105	
fines	80-90	
Batch, glass plants	85-90	30-45
Bauxite crushed	75-85	30-45
Beet pulp, dry	12-15	31
wet	25-45	31
Bones, crushed	35-40	50
Bone black	25	
Bonemeal	55-60	
Borax solid	110	
2"-3" lumps	60-65	40
1½"-2" lumps	55-60	30-45
½" screenings	55-60	30-45
fines	45-60	30-45
Brewers grain dry	25-30	
wet	55-60	
Brick hard	125	
soft	100	
Calcium carbide dust	70	30-45
Carbon black, powder	5	
pellets	25	
Cement Portland loose	75-85	
Chalk, solid	145	
2"-3" lumps	80-85	45
1½"-2" lumps	75-80	40-45
½" screenings	70-80	40-45
fines	65-75	40-45
Char sugar refinery	45	
Chips paper mill, softwood	12-20	
yellow pine	20-25	
logged fuel	22	
Clay dry loose	63	
brick, ground fine	90-110	35
Clinker cement	80-95	33
Coal anthracite solid	94	
large sizes	52-58	27
bituminous, solid	84	
run of mine	45-55	35
slack	43-50	27
lignite	45-55	
Cocoa	30-35	45
Co[illegible]	33	28
Cocoa nibs	35	26
Coconut shells broken	30	
Coffee, fresh berry	43	25
dried berry	40	30-45
Coke run of oven	25-30	30-40
breeze	24-35	40
Compost hothouse	50	45
Concrete, in place, stone	130-150	
in place, cinder	110	
wet, on conveyors	110-150	25-30
Copper ores, crushed	130-150	40
Copra	22	30
Corn grits	42	24
Cotton-seed cake, crushed	40-45	30-45
Cotton-seed hulls	12	45
Cotton-seed meal	35	37-45
Cotton-seed meats	45	30-45
Cryolite, solid	180	
2"-3" lumps	100-105	30-45
1½"-2" lumps	95-100	30-45
½" screenings	90-100	30-45
fines	75-90	30-45
Cullet	80-100	28-45
Culm, coal refuse	45-50	
Dolomite, broken	84-98	
Dolomite, crushed	90-100	40
Earth, as excavated dry	70-80	40
wet, mud	100-110	45
Epsom salts	70	
Fat	58	
Feldspar solid	165	
2"-3" lumps	90-95	30-40
1½"-2" lumps	85-90	30-40
½" screenings	80-90	40
fines	75-80	45
Filter press mud, sugar factory	70	
Fish, raw	52-55	
Fish, meal	40	
Flour, wheat, rye	40	31
Flue dust, blast furnace	115	
wet	150	
Fluorspar, solid	200	
2"-3" lumps	110-120	45
1½"-2" lumps	100-110	45
½" screenings	95-105	45
fines	85-95	45
Fly ash	30-45	30-45
Foundry refuse, old sand, cores	60-80	39
Foundry sand, loose	80-90	32
rammed	100-110	
Fullers earth, dry	30-45	35
oily	60-65	
Garbage, household	50	
Gashouse oxide, sponge	28-35	
Glue, animal, flaked	35	
vegetable, powdered	40	
Gluten meal	39	
Gneiss	90-95	
Granite, broken	80-95	35
Gravel, dry	90-100	35
wet	100-120	32
Gravel and sand mixed, wet	100-130	32
Guano, dry	70	
Gum arabic	90	
Gunpowder	63	
Gutta percha	60	
Gypsum, solid	140	
2"-3" lumps	75-80	30-45
1½"-2" lumps	70-75	30-45
½" screenings	70-80	30-45
fines	60-70	45

Table 5. Continued

Material	Weight lb/cu ft	angle of Repose Degrees
Hay loose	5	
pressed	8	
Hops brewery, moist	35	45
Ice, crushed	40	
India rubber, raw	58	
devulcanised	35	
Iron borings, machine shop	125	
Iron ore	130-180	35
Iron pyrites, solid	250	
2"-3" lumps	135-145	33
1½"-2" lumps	130-135	30-40
½" screenings	120-135	30-40
fines	105-120	30-40
Iron Sulphate, pickling tank		
wet	80	
dry	75	
Kieselguhr, infusorial earth	10-15	
Lead, white, pigment	250-260	
Lead ores	200-270	30-40
Lime, hydrated, pulverised	35-40	30-40
unslaked lump	60-65	
Limestone, solid	165	
2"-3" lumps	90-95	35
1½"-2" lumps	85-90	45
½" screenings	80-90	45
dust	75-80	45
Linseed cake, crushed	48-50	34
Linseed meal	44	35
Litharge, fumed	60	
skims	360	
Magnesium sulphate	70	25
Malt meal	36-40	
Malt sprouts	15	
Manganese oxide	120	
Manure, stable	25	
Marble, broken	95-105	35
Marl, as dug	79	
Mica solid	180	
2"-3" lumps	90-95	30
1½"-2" lumps	85-90	30
½" screenings	80-90	30-45
fines	75-80	30-45
Milk, dry, powder	36	45
malted	27	
Mortar (lime), wet	150	
Mushrooms	24	
Oxide, gas house sponge	28-35	
Oyster shells	80	
Paper pulp	60	
Paraffin cake, broken	45	
Peat solid dry	30	
loose, dry	20	
Petroleum coke	35-40	
Phosphate acid,		
ammoniated	52	35
fertiliser	60	35
pebble, dry	90	30-45
pebble, wet	100	30-45
rock broken, dry	75	35
rock broken, wet	85	35
Pitch	72	27
Plumbago, crushed	85-90	
Potash salts, sylvinite etc	80	
Pumice stone, ground	40	45
Quartz, solid	165	
2"-3" lumps	90-95	35
1½"-2" lumps	85-90	35
½" screenings	80-90	35
fines	70-80	40
Resins, powdered	30-40	30
Rice grits	40	30

Material	Weight lb/cu ft	angle of Repose Degrees
Rock, soft, excavated		
with shovel	100-110	
Rosin, lump	65	
Rubber	58	
reclaimed	35	
Salt, coarse	55	30
fine	45	30
Saltpetre	68	30-45
Sand, beach or river, wet	120-130	15-30
dry	90-100	30-45
foundry, loose	80-90	45
Sawdust	13	45
Sewage (sludge)	40-50	30-40
Shale, broken	90-100	30-45
crushed	85-90	25
Skinnings, slaughterhouse,		
refuse	75	
Slag, blast furnace, crushed	80-90	28
granulated, dry	60-65	
wet	90-100	
Slate, broken	70-95	28
Slurry, cement	90	39
Snow, fresh fallen	5-12	45
compacted by rain	15-50	30-40
Soap	50	
Soap flakes	10	30
Soap powder	30	40
Soda Ash, carbonate,		
dense	50-65	
light	30-40	
nitrate	85	
Starch	45	
Sugar, cane stalks	25	
raw	55-65	
refined	55	
Sulphur, solid	125	
2"-3" lumps	85-90	35
1½"-2" lumps	80-85	30-45
½" screenings	75-85	30-45
fines	65-75	30-45
Talc solid	165	
2"-3" lumps	90-95	38
1½"-2" lumps	85-90	38
½" screenings	80-90	38
fines	75-80	45
Tallow	58	
Tan bark, ground	55	
Tankage	40	
Turf dry	30	
Whitstone, broken	84-98	
Zinc ores, crushed	150-160	38
Zinc oxide	10-20	45
Zinc sulphate	60-75	44

Metals (Solid or compact weight)	Wt lb per cu ft
Cast Iron	450
Wrought Iron	480
Steel	490
Brass (cast)	505
Lead	711
Zinc	438

Grain	Weight lb/cu ft
Wheat	48
Barley	38
Shelled corn	45
Flour	56
Oats	26
Rye	45

A close approximation of the crushed weight of an ore or rock equals the solid weight divided by 1.75. Crushed ore weights should [illegible] by conveyors. [illegible] the type of mater[illegible]

Table 4. Suggested Normal Spacing of Belt Idlers [2].

b, Belt width (inches)	Troughing idlers Weight of material handled, lbs per cu ft						Return idlers
	30	50	75	100	150	200	
14	5.5 ft	5.0 ft	5.0 ft	5.0 ft	4.5 ft	4.5 ft	10.0 ft
16	5.5 ft	5.0 ft	5.0 ft	5.0 ft	4.5 ft	4.5 ft	10.0 ft
18	5.5 ft	5.0 ft	5.0 ft	5.0 ft	4.5 ft	4.5 ft	10.0 ft
20	5.5 ft	5.0 ft	4.5 ft	4.5 ft	4.0 ft	4.0 ft	10.0 ft
24	5.0 ft	4.5 ft	4.5 ft	4.0 ft	4.0 ft	4.0 ft	10.0 ft
30	5.0 ft	4.5 ft	4.5 ft	4.0 ft	4.0 ft	4.0 ft	10.0 ft
36	5.0 ft	4.5 ft	4.0 ft	4.0 ft	3.5 ft	3.5 ft	10.0 ft
42	4.5 ft	4.5 ft	4.0 ft	3.5 ft	3.0 ft	3.0 ft	10.0 ft
48	4.5 ft	4.0 ft	4.0 ft	3.5 ft	3.0 ft	3.0 ft	10.0 ft
54	4.5 ft	4.0 ft	3.5 ft	3.5 ft	3.0 ft	3.0 ft	10.0 ft
60	4.0 ft	4.0 ft	3.5 ft	3.0 ft	3.0 ft	3.0 ft	10.0 ft
66	4.0 ft	4.0 ft	3.5 ft	3.0 ft	3.0 ft	2.5 ft	8.0 ft
72	4.0 ft	3.5 ft	3.5 ft	3.0 ft	2.5 ft	2.5 ft	8.0 ft

Table 5. Idler Service Factor "A" [8].

Types of service	Factor A
Intermittent operation	
Less than 6 hours per day	6
Portable or temporary installations	6
Seasonal operation for stockpiling	12
Conveying materials over 120 lbs per cu ft	15
One shift operation	
Operation 6 to 9 hours per day	9
Sized material up to and including 80 lbs per cu ft	9
Sized material up to and including 120 lbs per cu ft	12
Sized material over 120 lbs per cu ft	15
Unsized material, limited in lump size only by belt width	15
Two shift operation	
Operation 10 to 16 hours per day	12
Unsized material up to and including 100 lbs per cu ft	12
Sized material, over 100 lbs per cu ft	15
Unsized material, limited in lump size only by belt width	15
Continuous operation	
Over 16 hours per day, all materials	15

Table 6. Material Weight and Factor "B" [1].

Maximum lump size (inches)	Factor B Material weight, lbs per cu ft						
	50	75	100	125	150	175	200
4	24	36	48	60	72	84	96
6	32	48	64	80	96	112	128
8	40	60	80	100	120	140	160
10	48	72	96	120	144	168	192
12	56	84	112	140	168	196	224
14	64	96	128	160	192	224	256
16	72	108	144	180	216	252	288
18	80	120	160	200	240	280	320

Table 7. Estimated Average Belt Weights, Lbs per ft Length [7].

Belt width (inches)	Weight of material carried, lbs per cu ft		
	30 to 74 (Light duty)	75 to 129 (Medium duty)	130 to 200 (Heavy duty)
14	2.5	3.0	3.1
16	2.8	3.5	3.6
18	3.1	4.0	4.1
20	3.5	4.5	4.6
24	4.2	5.7	6.2
30	5.3	7.2	8.0
36	9.2	9.6	11.5
42	10.7	11.5	13.8
48	13.6	14.2	16.6
54	15.3	16.9	19.3
60	17.7	19.4	21.4
66	19.0	21.8	23.6
72	20.3	24.3	25.7

Table 8. Roll Diameters and Size of Bearings from Series No [1].

Series number	Roll diameter (inches)	Shaft diameter (inches)
I	4 & 5	5/8
II	4 & 5	0.669 thru 3/4
III	4 & 5	3/4
IV	6	3/4
V	6	1 3/16 or 1 1/4
VI	7	1 [illegible] or 1 1/4

Table 9. Constants and Tensions Factors (C_W) [10].

Drive		Constant ratios $\frac{T_1}{T_2}$ for single pulley drive; $\frac{T_1}{T_2}$ for both pulleys of dual pulley drive		Slack side tension factors required for driving belt — Gravity Takeup	
Type	Arc of contact of belt on drive pulleys, degrees	Bare pulley	Lagged pulley	Bare pulley	Lagged pulley
Single Pulley	180	2.19	3.0	85	.50
Snubbed Pulley	200	2.39	3.39	72	.42
	210	2.50	3.61	67	.38
	215	2.55	3.72	64	.36
	220	2.61	3.83	62	.35
	230	2.73	4.07	.58	.33
	240	2.85	4.33	.54	.30
Dual Pulley	360	4.60	9.02	.26	.13
	380	5.25	10.19	.23	.11
	400	5.72	11.51	.21	.09
	420	6.25	13.00	.19	.08
	450	7.12	15.22	.16	.07
	500	8.66	21.21	.13	.05

Table 10. Factor "K_X" Values for Idler Roll and Shaft Diameters Listed [1].

$W_b + W_m$ lbs per ft	Tabular idler spacing S, from Table 8-3	K_x for idler roll and shaft diameters listed: 4 inch roll ¾ inch shaft a_1 = 1.26	5 inch roll ¾ inch shaft a_1 = 1.08	6 inch roll ¾ inch shaft a_1 = 0.90	6 inch roll 1¼ inch shaft a_1 = 2.13	7 inch roll 1¼ inch shaft a_1 = 1.80
20	4.5	0.2936	0.2586	0.2136	0.4869	0.4136
50	4.0	0.3490	0.3040	0.2590	0.5665	0.4840
100	3.5	0.4280	0.3766	0.3251	0.6766	0.5823
150	3.0	0.5220	0.4620	0.4020	0.8120	0.7020
200	3.0	0.5560	0.4960	0.4360	0.8460	0.7360
250	3.0	0.5900	0.5300	0.4700	0.8800	0.7700
300	3.0	0.6240	0.5640	0.5040	0.9140	0.8040

Table 11. "K_y" Values for Different Inclined Conveyor Slopes [1].

Conveyor Length (ft)	$W_b + W_m$ (lbs per ft)	Percent slope						
		0	3	6	9	12	24	33
		Approximate degrees						
		0	2	3.5	5	7	14	18
250	20	0.035	0.035	0.034	0.031	0.031	0.034	0.035
	50	0.035	0.034	0.033	0.032	0.031	0.028	[illegible]
	75	0.035	0.034	0.032	0.032	0.030	0.027	[illegible]
	100	0.035	0.035	0.032	0.031	0.030	0.026	0.023
	150	0.035	0.035	0.034	0.033	0.031	0.025	0.021
	200	0.035	0.035	0.035	0.035	0.03[illegible]	0.024	0.016
	250	0.035	0.035	0.035	0.035	0.033	0.021	0.018
	300	0.035	0.035	0.035	0.035	0.032	0.019	0.016
400	20	0.035	0.034	0.032	0.030	0.030	0.030	0.030
	50	0.035	0.033	0.031	0.029	0.029	0.026	[illegible]
	75	0.034	0.033	0.030	0.029	0.028	0.024	0.021
	100	0.034	0.032	0.030	0.028	0.028	0.022	0.019
	150	0.035	0.034	0.031	0.028	0.027	0.019	0.016
	200	0.035	0.035	0.033	0.030	0.027	0.016	0.014
	250	0.035	0.035	0.034	0.030	0.026	0.017	0.016
	300	0.035	0.035	0.034	0.029	0.024	0.018	0.016
500	20	0.03[illegible]	0.033	0.031	0.030	0.030	0.030	0.030
	50	0.034	0.032	0.030	0.028	0.026	0.024	0.02[illegible]
	75	0.033	0.032	0.029	0.027	0.027	0.021	0.019
	100	0.033	0.031	0.029	0.028	0.026	0.019	0.016
	150	0.035	0.03[illegible]	0.030	0.027	0.024	0.016	0.016
	200	[illegible]	0.035	0.030	0.02[illegible]	0.02[illegible]	0.016	0.016
	250	0.035	0.035	0.030	0.025	0.021	0.016	0.015
	300	0.035	0.035	0.029	0.024	0.019	0.018	0.018
600	20	0.035	0.032	0.030	0.029	0.029	0.030	0.030
	50	0.033	0.030	0.029	0.027	0.026	0.023	0.021
	75	0.032	0.030	0.028	0.026	0.024	0.020	0.016
	100	0.03[illegible]	0.030	0.027	0.025	0.022	0.016	0.016
	150	0.035	0.031	0.026	0.021	0.019	0.016	0.016
	200	0.035	0.031	0.026	0.021	0.017	0.016	0.016
	250	0.035	0.031	0.024	[illegible]	0.017	0.016	0.016
	300	0.035	0.031	0.023	0.018	0.018	0.018	0.018

Table 11 (Continued)

Conveyor Length (ft)	$W_b + W_m$ (lbs per ft)	Percent slope 0	3	6	9	12	24	33
		Approximate degrees 0	2	3.5	5	7	14	18
800	20	[illegible]	0.031	0.030	[illegible]	[illegible]	0.029	0.029
	50	[illegible]	0.029	0.028	[illegible]	[illegible]	0.021	0.018
	75	0.031	0.029	0.026	0.024	[illegible]	0.016	0.016
	100	0.031	0.028	0.025	0.022	0.020	0.016	0.016
	150	[illegible]	0.028	0.023	0.019	0.017	0.016	0.016
	200	[illegible]	0.027	0.021	0.016	0.016	0.016	0.016
	250	0.035	0.026	0.020	0.017	0.016	0.016	0.016
	300	0.035	0.025	0.018	0.018	0.018	0.018	0.018
1000	50	0.031	0.028	0.026	0.024	0.023	0.019	0.016
	75	0.030	0.027	0.024	0.022	0.019	0.016	0.016
	100	0.030	0.026	0.022	0.019	0.017	0.016	0.016
	150	0.033	0.024	0.019	0.016	0.016	0.016	0.016
	200	[illegible]	0.023	0.017	0.016	0.016	0.016	0.016
	250	0.033	0.022	0.017	0.016	0.016	0.016	0.016
	300	0.033	0.021	0.018	0.018	0.018	0.018	0.018
1400	50	0.029	0.026	0.024	[illegible]	0.021	0.016	0.016
	75	0.028	0.024	0.021	0.019	0.016	0.016	0.016
	100	0.028	0.023	0.019	0.016	0.016	0.016	0.016
	150	0.029	0.020	0.016	0.016	0.016	0.016	0.016
	200	0.030	0.021	0.016	0.016	0.016	0.016	0.016
	250	0.030	0.020	0.017	0.016	0.016	0.016	0.016
	300	0.030	0.019	0.018	0.018	0.018	0.018	0.018
2000	50	0.027	0.024	0.022	0.020	0.018	0.016	0.016
	75	0.026	0.021	0.019	0.016	0.016	0.016	0.016
	100	0.025	0.020	0.016	0.016	0.016	0.016	0.016
	150	0.026	0.017	0.016	0.016	0.016	0.016	0.016
	200	0.024	0.016	0.016	0.016	0.016	0.016	0.016
	250	[illegible]	0.016	0.016	0.016	0.016	0.016	0.016
	300	[illegible]	0.018	0.018	0.018	0.018	0.018	0.018

Table 12. Values of "C" (Weights of Moving Parts) [7].

Value of "C" Based on	14"	16"	18"	20"	24"	30"	36"	42"	48"	54"	60"
Troughing Idler Spacing	5'0"	5'0"	4'6"	4'6"	4'0"	4'0"	3'6"	3'6"	3'6"	3'6"	3'6"
Return Idler Spacing	10'0"	10'0"	10'0"	10'0"	10'0"	10'0"	9'0"	9'0"	9'0"	7'0"	7'0"
Weight of Belt, lbs per foot	2.5	2.8	3.5	4.5	5.0	8.5	11.0	13.0	16.0	18.0	21.0
Value of "C"	15	16	19	21	25	31	44	50	60	69	77

Table 13. Weights of the Rotating Parts of Idlers [3].

Belt Width Inches	B & B Series Ball Bearing Idlers 4" Dia Troughing	B & B Series 4" Dia Return	B & B Series [illegible] Dia Troughing	B & B Series [illegible] Dia Return	Permaseal Cast Iron Idlers 6" Dia Troughing	Permaseal Cast Iron 6" Dia Return	Permaseal Idlers Type MD 4" Dia Return	Type MD 5" Dia Troughing	Type MD 5" Dia Return	Type MD 6" Dia Troughing	Type MD 6" Dia Return	Type HD 6" Dia Troughing	Type HD 6" Dia Return	Type HD 7" Dia Troughing
14	12.5	[illegible]	16.1	12.8			10.6	17.6	[illegible]					
16	13.5	[illegible]	17.5	[illegible]			11.7	18.9	14.[illegible]					
18	14.5	[illegible]	18.3	[illegible]	15.0	45.0	12.8	20.3	16.1	25.7	[illegible]			
20	15.6	13.1	20.1	15.5	46.5	44.5	13.9	21.8	17.5	28.7	23.1			
24	17.7	15.1	22.7	19.1	53.0	55.5	16.0	24.6	20.1	32.3	26.7			
30	20.9	18.2	26.7	[illegible]	60.0	66.5	19.3	28.7	24.2	37.8	32.0			
36	24.0	21.2	30.6	[illegible]	69.0	77.5	22.5	32.9	28.2	43.5	37.3	69	59	69
42					76.3	88.5	25.7	37.1	32.3	49.1	42.7	77	67	98
48					83.5	99.0	29.5	41.3	36.8	54.6	48.5	85	75	107
54					...			45.4	40.8	59.9	53.9	93	83	117
60								49.6	45.0	65.8	59.3	101	91	126
66												109	99	135
72								...				117	107	144

Table 14. Maximum Allowable Working Tension for Various Belt Carcass Constructions [6].

Splice	Cotton Duck Belts — Designation				
	28 oz.	[illegible]	[illegible]	[illegible]	[illegible]
Vulcanized	33	35	40	50	60
Metal Fastened	27	30	35	45	50

Splice	Cotton — Nylon Belts — Designation				
	[illegible]	[illegible]	50	[illegible]	[illegible]
Vulcanized	35	45	55	60	75
Metal Fastened	30	40	45	50	60

Splice	Rayon Fabric Belts -- Nylon or Rayon Fill — Designation		
	Light	Medium	Heavy
Vulcanized	45	55	70
Metal Fastened	40	50	65

Table 15. Take-up Travel Requirements [3].

Operating belt tension, in per cent of rated belt tension	Minimum length of takeup of an average carcass belt in per cent of conveyor centers — Average carcass
100	¼ - 1½
75	½ - 1