THE DESIGN OF BELT CONVEYORS FOR BULK SUGAR HANDLING

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1. Introduction

Depending on the condition of the sugar and the quantities to be handled, many different methods are employed for transporting sugar in bulk, including, *inter alia:—*

Screw conveyors;
Grasshoppers;
Belt conveyors;
Bucket elevators.

Most of the above-mentioned types of conveyors may be seen in almost any sugar factory, and, as any sugar engineer will be only too quick to explain, each method has its own peculiar problems which suit it to certain applications.

Belt conveyors have their attraction for most applications because of the small number of wearing parts, which results in low maintenance costs; and the absence of relative movement between the sugar and conveyor components with which it is in contact, which results in minimal product degradation. However, they can be extremely difficult to install successfully. In fact, one well-known sugar engineer who has a number of belt conveyors handling his final sugar was heard to comment that "his belt conveyors were fine, they would take away as much sugar as you can put on them; the snag is, they bring most of it back again."

It may be stated that almost anyone could successfully design a belt conveyor to carry a given quantity of sugar, or any other commodity. The secret of the successful design of a conveying system lies in the design of the transfers to and from the conveyor, to ensure maximum loading of the belt with minimum spillage.

Where the quantities of sugar to be handled are low (less than 50 tons per hour) and conveying distances are comparatively short, other methods of conveying sugar are frequently found to be more suitable despite higher maintenance and operating costs; but once high conveying rates and long distances become necessary, as at the Sugar Terminal, there would appear to be no alternative to the belt conveyor, and under these circumstances the control of spillage becomes of paramount importance. At the Sugar Terminal certain of the conveyors are designed for a duty in excess of 1,000 tons per hour, at which duty a spillage of only 0.1% will leave 24 tons of sugar per day to be shovelled off the floor. This is obviously totally unacceptable, and a thorough knowledge of the behaviour of sugar at a belt transfer becomes a prerequisite to designing an acceptable system.

The question may be asked, "What about the possibility of pneumatic conveying?" The authors are not aware of a successful pneumatic conveying system for raw sugars, particularly where low pol varieties have to be handled, due to the sticky nature of the material to be carried, and a pneumatic conveying system for refined sugars would be hazardous in the extreme due to the possibility of the sugar dust forming an explosive mixture with the air.

2. Selection of Conveyor Components

This subject is dealt with exhaustively in trade literature, and it is only proposed to mention the main points to be considered briefly.

Assuming that the rate at which it is desired to transport the product has been established, it is then necessary to decide on the belt speed, belt width, idler type and type of belt in order to establish the basic parameters of the conveyor design. All the above variables are to a greater or lesser degree inter-dependent and the success and economy of the final design depends on achieving the optimum balance between them.

2.1 Belt Speed

Let us in the first instance examine the effect of varying belt speeds. The range of speeds which has been used in belt conveyor design varies from approximately 150 feet per minute to as high as 1,500 feet per minute. In general, speeds above 300 to 350 feet should only be contemplated for high conveying rates where it is necessary to use belts wider than 30″ in order to achieve the desired material transfer rate. The higher the belt speed the more difficult it is to load the belt without spillage. Wider belts alleviate the loading problem and the highest belt speeds have been used on belts of 48″ and 54″ width. This choice of parameters (i.e. 48″ width and 1,500 ft. per minute belt speed) gives material transfer rates, depending on the density of the material being handled, of 2,000 to 3,000 tons per hour in a deep-troughed belt. Thus, in general terms, it may be stated that for belts less than 30″ wide belt speeds in excess of 400 ft. per minute should be avoided, while belt speeds above 1,000 ft. per minute should be avoided on belts less than 48″ wide. It is axiomatic that provided the belt can be adequately loaded the carrying capacity is proportional to the belt speed. Unfortunately, with narrow belts at high speeds it becomes increasingly difficult to achieve an adequate degree of loading without excessive spillage of product at the transfer points.

2.2 Idler Type

Drawings of typical idlers of the various types available are shown in Figure 1. For conveying sugar it is only necessary to consider the 20°, 30° and 45° equal roll idlers and the flat return belt rubber tread idler. The other types of idler shown, such as the troughed-belt cushion idlers and the unequal idlers are special purpose idlers for lumpy products or for picking or sorting belts and such special applications. The 45° troughing idler gives the greatest carrying capacity for any given belt width, but it is essential that an adequately flexible belt be used with it to ensure that sufficient contact is maintained between the belt and the horizontal roll of the idler under no-load conditions if belt tracking problems are to be avoided. It is only with modern materials that it has been possible to produce sufficiently flexible belts to operate satisfactorily with 45° troughing idlers, so that the use of these is a comparatively recent innovation in conveying practice. The five-roll idler which is illustrated is in use on the existing plant at the Sugar Terminal, but is only really necessary to provide maximum loading on very inflexible belts.

The type of troughing idler, belt width and belt speed must be selected in conjunction to provide a conveyor which will carry the required quantity of product, and basic parameters to assist in the calculation of carrying capacities may be found in the various manuals on conveyors. The choice of belt speed and type of idler dictates the choice of belt construction suitable for the particular conveyor. Where high duties are involved, the 45° idler is the obvious choice while at lower duties there may be distinct merit in the 30° or even the 20° idler.

For sugar conveying the rubber tread type of return idler has been found to be the most satisfactory as it presents the least surface to pick up sugar on the return run of the belt.

The selection of the type of belt can be one of the greatest problems in conveyor design, and in handling sugar there are many factors to be taken into account in selecting belts. In sugar terminals there is good reason to avoid rubber belts as since the catastrophic fire at Townesville Sugar Terminal in Australia all insurance companies apply a large loading on premiums if rubber belts are installed. Thus it is essential that neoprene or P.V.C. belting is used. It has been found in Australia that P.V.C. belting is easier to clean than neoprene belting as sugar does not appear to adhere to it as strongly. We have as yet insufficient experience with P.V.C. belting in this country to comment on this.

Apart from the covers, there is now available a wide selection of fabrics for the belt carcases. These include cotton, nylon, nylon-cotton, terylene, rayon and even steel wire. These materials all have their particular merits which suit them to particular applications, but this is such a vast subject that it could well form the subject of a paper on its own. Suffice at this stage to state that the original installations at the Sugar Terminal used neoprene belts with cotton carcase, while the belting selected for the extensions consists of a nylon-cotton carcase with P.V.C. covers.

3. Belt Training

A major practical problem in the operation of belt conveyors is ensuring that the belt runs reasonably centrally on the idlers. If the belt runs off too far it is liable to be damaged by contact with the conveyor structure, while even before this stage is reached it is possible that excessive spillage may result from a belt running eccentrically. It is common practice to install training idlers to correct the tendency of belts to run off. It has been found in practice that while training idlers may work well on low-speed belts they do not appear to materially assist in tracking high-speed belts. Also, where very flexible belts are installed to run on 45° troughed idlers the belt tends to ride up over the guide rolls of the training idlers and this can cause considerable damage to the belt. On high-speed belts it has been found to be better practice to line up all idlers and the head and tail pulleys extremely accurately and to dispense entirely with training idlers. Any slight tracking problems which may occur subsequently may be corrected by slight adjustment of the last troughing idler before the head pulley or the last return idler before the tail pulley.

On slow-speed belts training idlers can perform a very valuable service, but they cannot be relied upon to ensure that a belt runs true when intermediate idlers are not sufficiently accurately set up. It is essential, therefore, that all conveyor components be extremely accurately aligned before any conveyor is commissioned.

It has been observed at the Sugar Terminal that, despite the most careful alignment of idlers and head and tail pulleys, the tracking characteristics of the belts vary during the first few weeks of operation. Thus it is necessary to observe continually a new belt and occasionally adjust idlers to maintain the tracking of the belt during the first few weeks of operation. Once the belt has settled in no further adjustments are found necessary over a long period of operation. No training idlers have been fitted on any of the conveyors in the new section of the Sugar Terminal. However, side limit switches have been fitted at the head and tail ends of all belts to trip the conveyors out in the event of a belt tracking off seriously.

4. Transfer Chutes

Transfer chutes, as the name implies, are for the purpose of transferring the conveyed material from one conveyor belt to the next one in the sequence.

Transfer chutes are the heart of the design of any conveyor installation and the success of the design of the chutes can make or mar the whole installation. The object is to transfer all the conveyed material from one belt to the next with as little loss of height as possible and without spillage.

Transfer chutes are of two basic types which operate on entirely different principles. For our own convenience we have called these (a) feeder box type, and (b) curtain transfer type.

It has been found in practice that a mixture of design features of the two types of chute usually results in unsatisfactory performance.

The feeder box type is probably the best known and may take the form of a large hopper with a trouser leg outlet to guide the material right down to the receiving belt. The velocity of sugar reaching the receiving belt is often fairly low and therefore the chutes need to be relatively large. Because of this, and because it has been found in practice that valley angles of chutes (when handling sugar) must be not less than 55° to the horizontal as holding up of sugar will occur if this condition is not realised, a relatively large drop is required between the feeding and receiving belts. This is usually costly on account of extra civil works being required and, incidentally, more power is required to raise the sugar to the greater height.

The curtain transfer type of chute on the other hand works best with a minimum drop. In this type of transfer an attempt is made to form the profile of sugar leaving the feeding belt into a curtain of rectangular cross section which is allowed to fall free on to the receiving belt. The sugar is then guided by skirt plates until it has accelerated to belt speed.

The curtain type chute consists essentially of a flat plate ("feed plate") on to which the trajectory of the sugar leaving the feeding belt impinges. The sugar spreads across the feed plate and forms a curtain which drops on to the receiving belt. The ideal curtain has a rectangular cross section, but the chief difficulty is to obtain such a curtain. In order to restrict the curtain to reasonable dimensions it has been found necessary in practice to put sides on the feed plate. Unfortunately, these sides usually have the effect of spoiling the rectangular form of the curtain (Fig. 2) which, in turn, causes turbulence on the receiving belt, thus hindering the acceleration of sugar up the belt.

The difficulty of obtaining a uniform curtain of sugar has been referred to already, and so far we have only been moderately successful in this. If a flat vertical feed plate is used the sugar splashes on the plate and boils upwards and outwards. The outward boil has the effect of causing a lot of sugar to be constrained by the side plates which, as mentioned above, cause undesirable turbulence on the receiving belt.

It has been found that if the upward boil can be eliminated, the outward boil is reduced. This can be done by curving the feed plate so that the trajectory hits it without shock. It will be realised immediately that such a condition cannot exist as the angle of incidence of the sugar to the feed plate varies with the depth of the sugar profile. Furthermore, variations in the load carried by the belt will give different depths of profile with the attendant variations in incidence angle. Any such curve, therefore, must be a compromise.

It has been found that a piece of conveyor belting hanging in the chute (Fig. 2) is remarkably effective as an alternative to the curved feed plate and has the advantage that it adjusts its curve automatically with fluctuations in load. This has the added advantage that sugar does not build up as rapidly on a flexible surface which is continuously flexing, as on a rigid one.

A disadvantage of the curtain type chute is the velocity of the sugar when it reaches the receiving belt. In falling vertically it accelerates rapidly and attains a velocity equal to approximately eight times the root of the distance through which it falls. This may be so great, even with a very small fall, that the sugar flattens itself out on the belt and a flat or even hollow profile results. This means that belts cannot be fully loaded. A condition which aggravates this state of affairs, particularly on a steeply climbing receiving belt, is the acceleration of the sugar up the belt. It sometimes takes some three to four feet for the sugar to reach belt speed, and, as it slips down the belt, it appears to form a flatter profile.

All the difficulties referred to above have a most pronounced effect when the feeding belt is at right angles to a steeply climbing receiving belt, especially if the latter is narrow. This appears to be the most difficult transfer.

When feeding on to a level belt the form of the curtain is not so important. The curtain type transfer is new to us at least and seems to work well. However, it is thought that if the velocity of the sugar reaching the belt could be reduced without the risk of choking the whole chute, it could be even more effective.

The feeder box chute is probably better suited to belts operating below 500 feet per minute, whereas the curtain type is probably better with belts operating above, say, 600 feet per minute.

The curtain type at low speed is not satisfactory because the trajectory leaving the head pulley of the feeding belt never, or barely, reaches the feed plate, with the result that a curtain is not formed and the sugar falls out of control on to the receiving belt.

A necessary evil on both types of chutes is the dribble plate. This serves two functions. Firstly, it directs sugar which is late leaving the feeding belt on to the receiving belt, especially under start-up and stopping conditions before the full trajectory has been formed, and, secondly, it catches sugar spray from the cleaning devices (referred to later) and directs it on to the receiving belt. The dribble plate should be as near vertical as possible, but in any case not less than 55° to the horizontal. It should run from as far back as possible, consistent with the angle requirement to leave maximum space for belt cleaning gear in the chute.

Chutes generally should be as open as possible to allow easy access for cleaning.

4.1 Guide Plates

These may be attached to the lower edge of the feed plate to provide a degree of adjustment to the central loading of the receiving belt (Fig. 2). This is an important aspect of chute design as eccentric loading of belts can be a major cause of problems in tracking the belts.

4.2 Skirt Plates

Skirt plates are devices for constraining the sugar on the receiving belt, and normally run a few inches back down the belt from the rear end of the chute to about two feet in front of the chute.

The skirt plate normally consists of a steel plate 6″ to 8″ high which terminates about 2″ above the surface of the belt. A strip of soft rubber is clamped to the metal plate and extends downwards until it is just clear of the belt. It is undesirable to have the belt and skirt rubber actually in contact as excessive belt wear can take place if heavy contact occurs.

The whole assembly should be vertical and set as close to the edge of the belt as possible, consistent with avoiding spillage if the belt tracks off within normal limits, i.e. the skirt would normally be set about 3″ in from the edge of the belt.

A degree of adjustability in the whole skirt assembly is desirable, but it is essential that the skirt rubbers can be adjusted.

On climbing belts it is desirable to have a back plate fitted between the two skirt plates, but this should not be so far forward as to interfere with the curtain (Fig. 3).

5. Belt Cleaning

The object of cleaning belt conveyors is (a) to prevent spillage on the floor under the return run of the conveyor, (b) to prevent excessive build-up on the belt, and (c) to prevent build-up of sugar on return and other idlers which could cause bad tracking and rapid belt wear.

To date 100% cleaning has not been achieved but spillage has been reduced to tolerable levels. The whole problem of cleaning is aggravated by the need to carry different types of sugar on the same belts consecutively. For instance, the application of a water spray on the belt has a wonderful effect with sticky sugar, but simply makes a sticky mess with dry sugar. A number of different methods are available for getting sugar off the belts and broadly these comprise scrapers, brushes and water sprays.

5.1 Scrapers

One of the most effective methods used in Australia is a steel knife-edged scraper, spring loaded against stops, just clear of the belt at a little after 3 o'clock on the head pulley. This has a leading-edge radius of about 1/32″ (not more) and is arranged to fly clear of the belt in the event of build-up taking place on the head pulley, thus preventing the belt from being damaged. Such a scraper would plough off the bulk of the sugar adhering to the belt and the remainder would be removed by a rotating brush.

The use of such a scraper presupposes a head drum which is accurately machined if it is to be effective.

A scraper, currently in use at the Sugar Terminal, which appears to work tolerably well consists of a "Linotex" blade in contact with the belt set at a trailing angle of about 5° at about 6 o'clock to the head pulley. These scrapers are counterbalanced by weights and are not backed up by brushes. Another rubber scraper also in use and which also appears to work quite well when properly adjusted is set like the steel-edged scraper mentioned above, but in contact with the belt, i.e. this scraper has a leading-edge set tangentially but the whole scraper assembly is trailing. It is found that under certain conditions this scraper is prone to chatter. It has been found desirable to use tension springs rather than weights to hold the scraper against the head pulley with positive stops to limit the pressure of the blade on the head pulley to ensure continuous contact between the scraper and the belt.

5.2 Brushes

Experiments are currently in progress to establish the value of this type of cleaning device. Australian practice is to use a rotating brush with stiff nylon bristles arranged in tufts on a helix. The brushes are about 8″ diameter and rotate at about 1,000 r.p.m. The brush should be set so that the bristles lightly touch the belt. The stickier the sugar the higher the speed requires to be. The speed in any case should be such as to make the centrifugal force more powerful than the stickiness of the sugar, otherwise the brush will clog and become useless in a short space of time. The effective use of the brush also presupposes a true head drum.

The brush should be mounted in the chute so that all sugar removed from the feeding belt will fall on to the receiving belt either directly or by means of the dribble plate.

The brush must be so arranged that it can be quickly and easily dismantled for cleaning by an unskilled or semi-skilled person. If this cannot be achieved the brush will eventually clog and cease to be effective.

It must be located out of the path of the bulk of the sugar, and must be preceded by a scraper to remove bulk sugar carry-over which tends to clog the brush extremely quickly.

5.3 Water Sprays

Spraying water in small quantities on the belt just before the loading point makes a big contribution to belt cleanliness with sticky sugar. With dry sugar the problem is aggravated. Thus in general it is found advantageous to use water sprays with low pol sugar and not to use them with high pol.

5.4 Air Jets

Experiments have been carried out using an air jet to clean the sugar off the belt. Whilst in the short term it was possible to see a clean strip down the belt where the jet had been, in the long term no difference could be noticed. Furthermore, it was calculated that about 20 h.p. would be required for each belt and the project was abandoned.

5.5 Slatted Pulley

A device commonly in use by conveyor manufacturers is the slatted beater pulley. This is often used to increase wrap round a driving pulley or on either side of a drop tension gear. They do shake the belt to a degree and in so doing cause some sugar to fall off the belt. Unfortunately, sugar which falls off in this way can usually only be reclaimed by hand and as a cleaning device we do not attach much importance to them.

6. Protective Devices

Malfunction of conveyors can cause considerable damage, particularly to the belts, so it is necessary to consider carefully means for detecting malfunctions so that the conveyors may be stopped before excessive damage has been caused.

Further, it is a requirement of the Factories Act that provision be made for emergency stopping of conveyors from any position adjacent to them. At the Sugar Terminal all emergency stops are interlocked through a main central control station so that in the event of any fault on any conveyor, all associated conveyors are also tripped out to prevent spillage of sugar. The central control console also includes fault annunciator panels to indicate which tripping device initiated stopping of any particular conveyor system to assist in rapidly tracing the cause of the fault.

The safety devices fitted include, apart from the normal overload and short circuit trips in the switchgear for each conveyor, the following:—

(a) Trip wire switches fitted on the operating side of each conveyor with trip wires running the full length of the conveyor between head and tail pulley for emergency manual tripping of the conveyor.

(b) Side limit switches on the belts adjacent to the head and tail pulleys to trip out the conveyors in the event of a belt tracking off to a degree which may cause it to rub against the structure and consequently damage the belt.

(c) Underspeed switches, normally fitted to the tail pulley of each conveyor to trip the conveyor in the event of a drive losing traction, which may cause local overheating of the belt at the drive with consequent serious damage.

(d) Trip switches operated by the overtemperature trip on the fluid coupling in each conveyor drive.

(e) Silent ratchet back stops fitted to the head drum of each inclined conveyor to prevent the conveyor running backwards and depositing its total load of sugar on the floor at the tail pulley in the event of failure of the final chain drive.

7. Discussion

In the paper an attempt has been made to cover most of the broad problems associated with the design of high-speed belt conveyors for handling granular materials, particularly sugar, Unfortunately, at the time of writing it has not been possible to carry out a detailed assessment of the success of the designs which have resulted from the considerations mentioned above as the conveyors have only recently been commissioned, and the belt-cleaning gear in particular has not been properly tested as yet. However, before the paper is presented it is expected that an opportunity will have arisen to examine the performance of these conveyors thoroughly and to report further during discussion of the paper.

One of the main objectives of the careful consideration which has been given to the design parameters for these conveyors has been to attempt to eliminate, as far as possible, the necessity to complete the design of belt transfers by trial and error (with the assistance of an oxy-acetylene cutting torch) during the conveyor commissioning period.

Although this end has not been entirely achieved, experience gained on the first inloading conveyors commissioned has enabled the commissioning of the outloading system, which is now in operation, to proceed with a minimum of adjustment.

The new design of the outloading system of the Sugar Terminal and certain modifications to the existing outloading conveyors, the Servo Balans and the shiploaders has enabled the outloading rate to be increased from a steady rate of approximately 600 tons per hour to a rate which will probably exceed 800 tons per hour. In fact, the best loading rate achieved thus far has been 833 tons in one hour, which will be exceeded when a few final adjustments have been incorporated and more experience has been gained in operating this plant.

The designed intake rate for the new conveyors is 1,200 tons per hour maximum, which will in due course be associated with a new Rail Intake Station capable of a sustained intake rate of 800 tons per hour. However, this work has had to be delayed for redesign to accommodate the possibility that the Railways are considering, in the foreseeable future, introducing special bottom dump hopper cars for the handling of bulk sugar. The new Rail Intake Station is only scheduled to be ready for the beginning of the 1969/1970 sugar season. The intake rate is therefore limited at present to about 450 tons per hour by the existing intake plant.

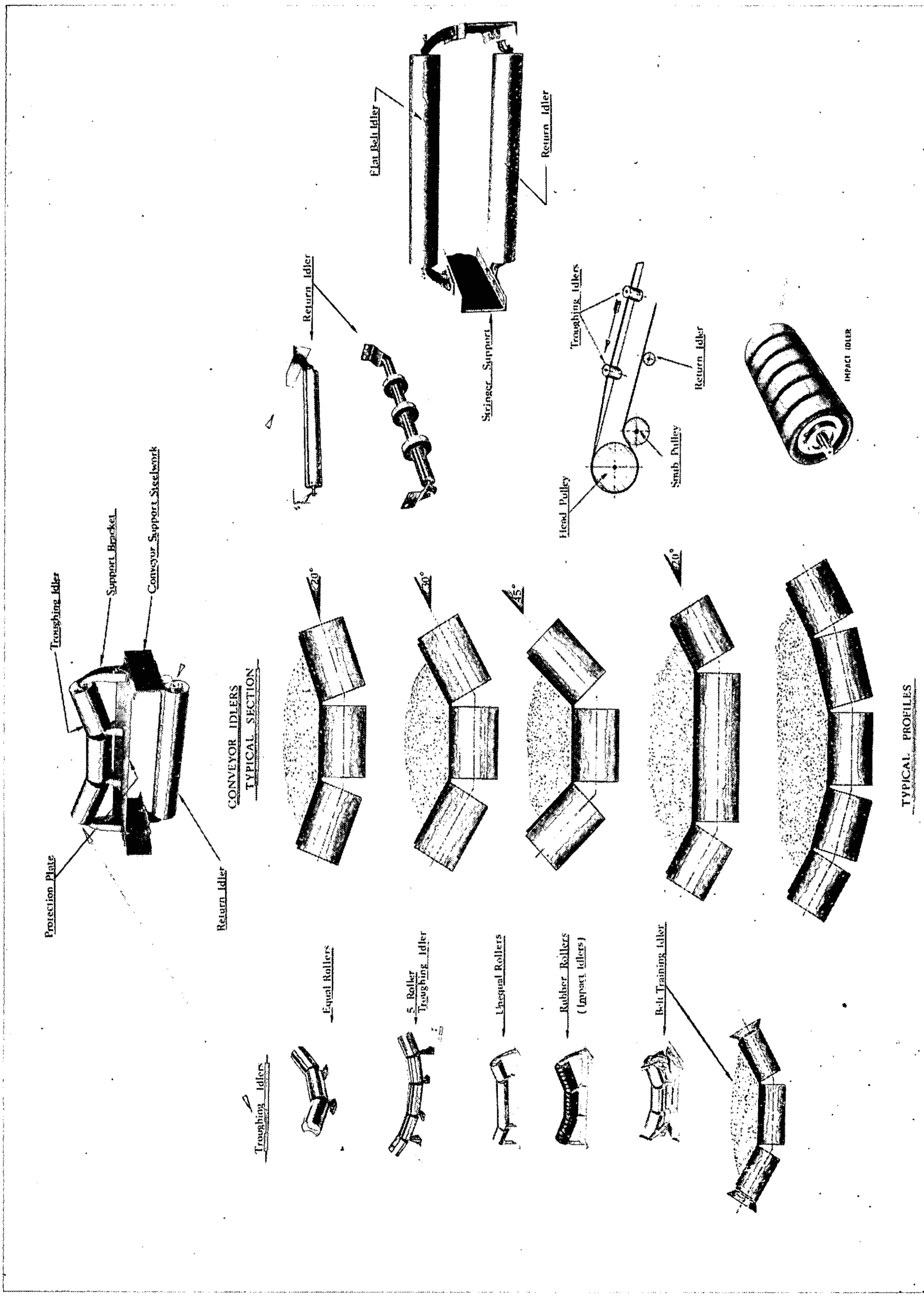

FIG.1 TYPICAL CONVEYOR COMPONENTS

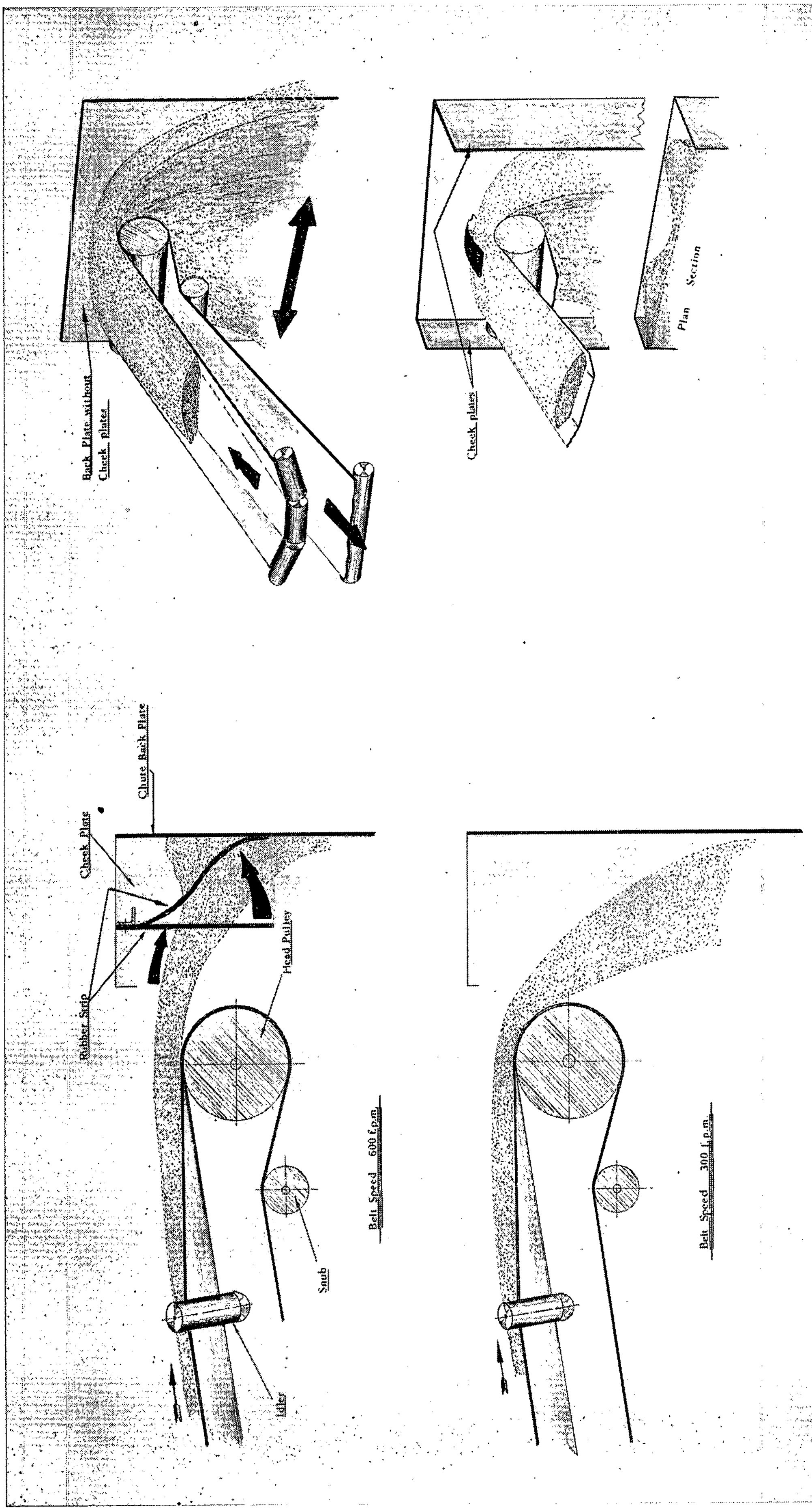

FIG. 2 TYPICAL DISCHARGE TRAJECTORIES

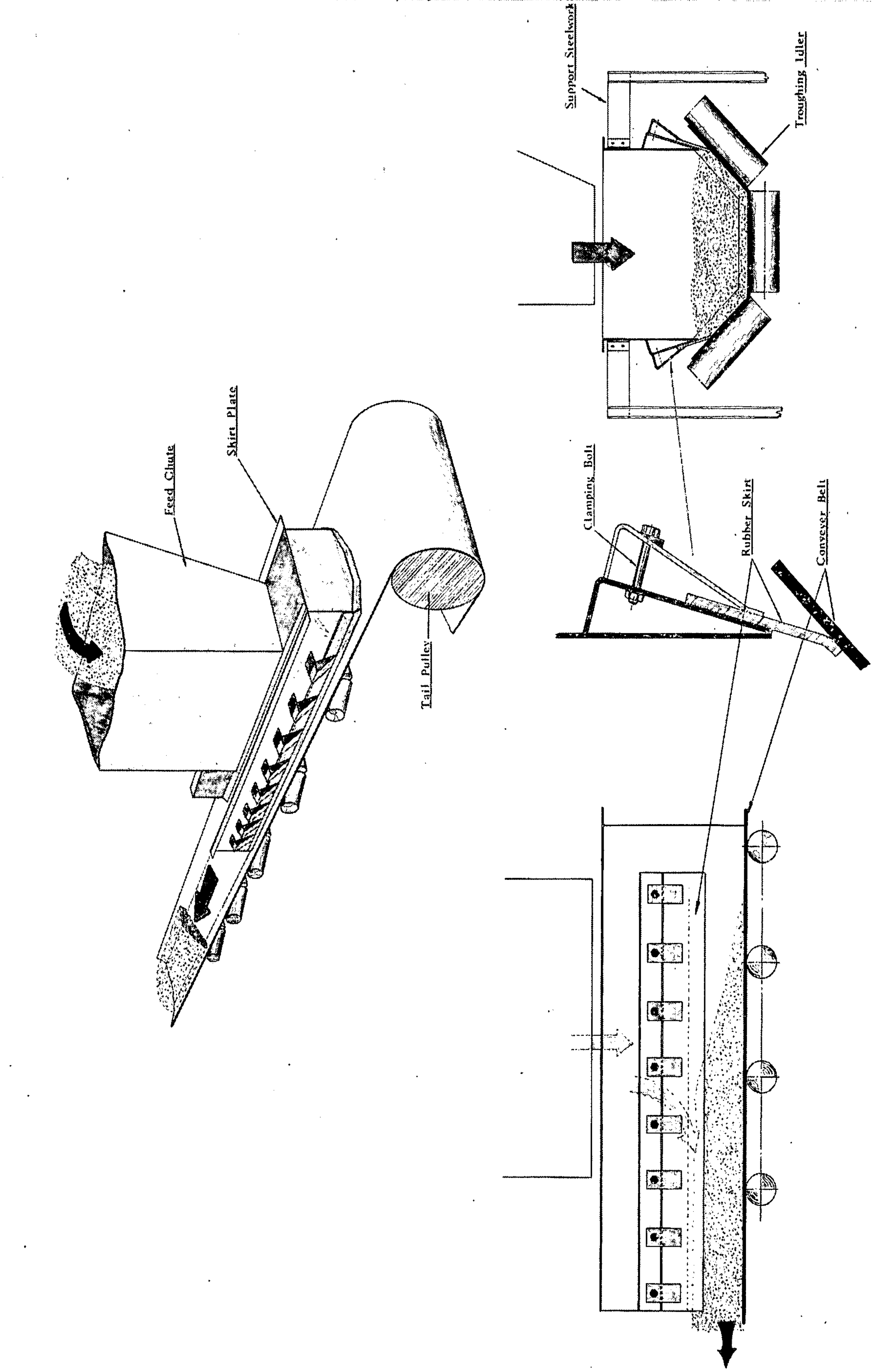

FIG. 3 TYPICAL SKIRT DETAILS

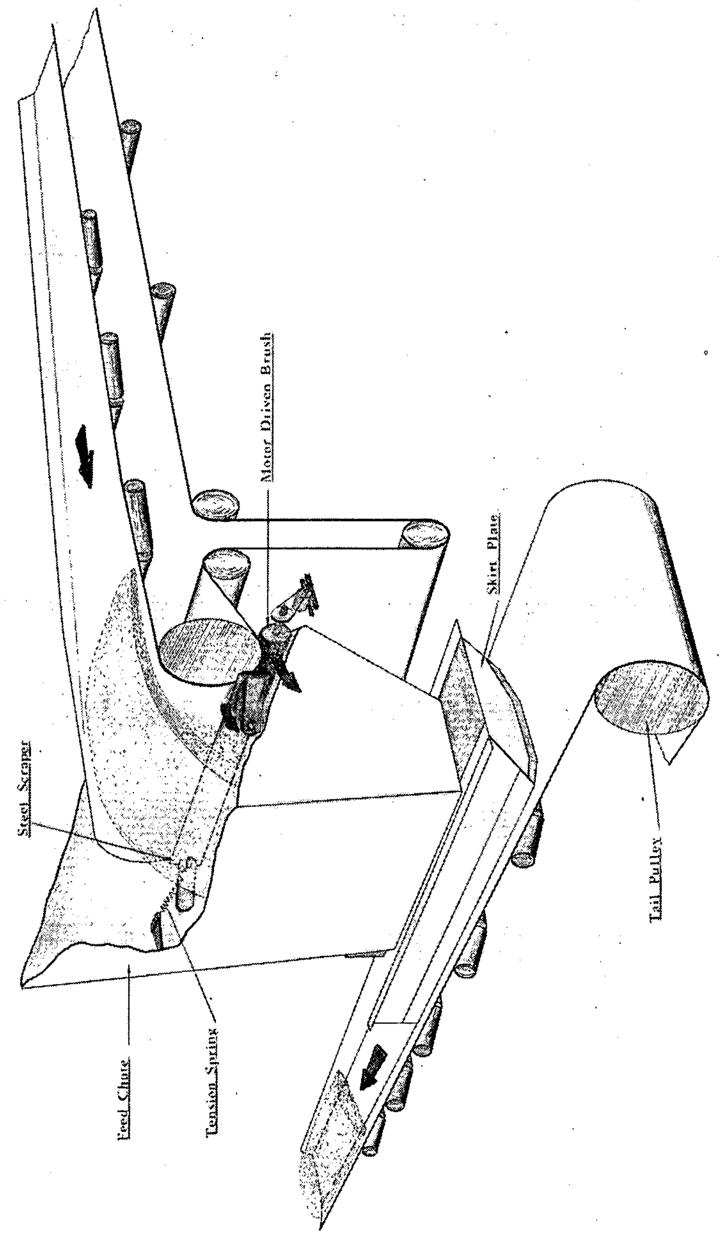

FIG. 4 TYPICAL BELT CLEANING GEAR

Discussion

Mr. Gunn (in the chair): I would first like to know if the belts used at the terminal are spliced or whether metal fasteners are used.

Secondly, if they are spliced, has a tightly stretched piano wire been tried as a scraper?

Dr. Guthrie: All belts are spliced. The piano wire has been tried but due to vibration, particularly on the wider belts, a fair amount of sugar escaped underneath. The piano wire also broke frequently.

Mr. Andrews: Has Dr. Guthrie any experience of stainless steel belting for handling sugar?

Dr. Guthrie: We considered it, together with other types of belt, but decided it would not be suitable for this application.

Where tensions are high, steel cord belting is excellent.

Mr. Chiazzari: Has the Terminal had any trouble with sweating, caused by humidity, so that moisture collects on the belt?

Mr. Peirson: We have not noticed anything of this nature though possibly it does occur and the moisture is immediately absorbed by the sugar.

Mr. Chiazzari: We have had to install fans to blow hot air across our conveyors.

Mr. Steffen: What does Dr. Guthrie think of the merits of a screw conveyor, or grasshopper conveyor, as against a belt conveyor for carrying small tonnages of sugar over a short distance.

Dr. Guthrie: At small tonnages the choice is difficult. In general if it is possible to use a belt conveyor it will be more economical than a screw conveyor or a grasshopper, particularly with regard to maintenance. There is more degradation of the product from a screw conveyor than from a belt, although this does not apply at all with a grasshopper.

Using belt conveyors the Terminal has maintained, for one hour, a loading rate of 860 t.p.h.