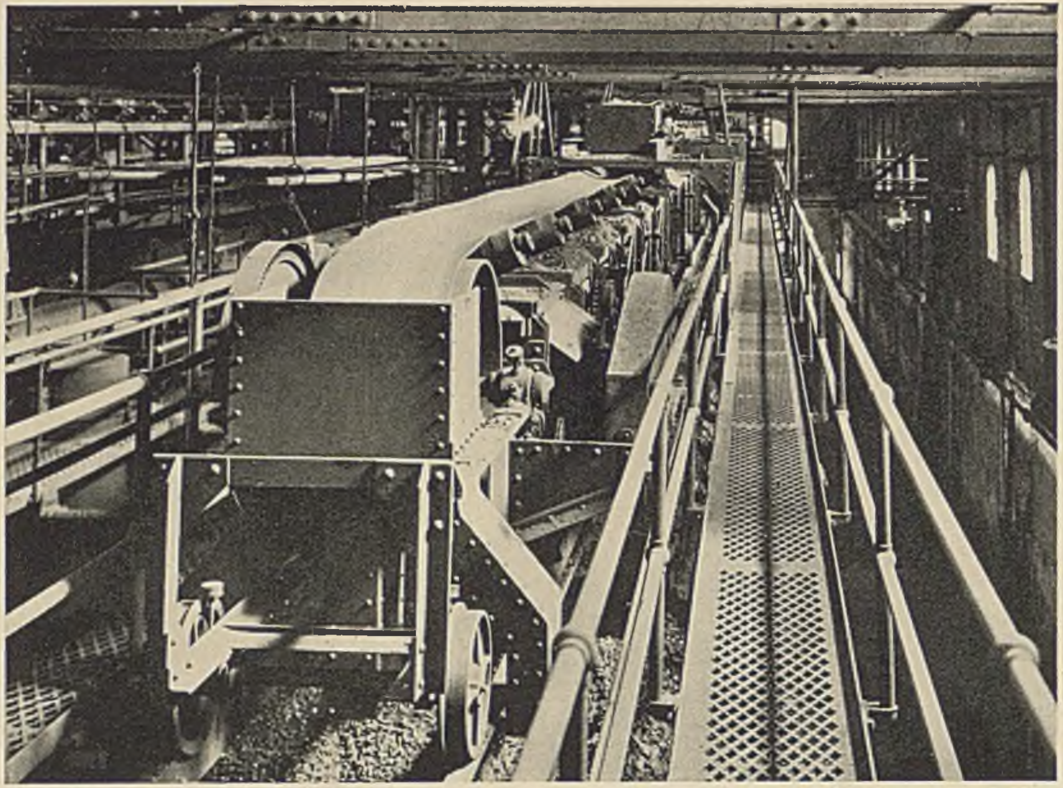
CONVEYING MACHINERY

W. H. ATHERTON



18-inch Shuttle Belt Conveyor over Coal Bins in a London Gasworks.

[*Frontispiece.*

CONVEYING MACHINERY

BY

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WITH NUMEROUS ILLUSTRATIONS AND TABLES

54

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PREFACE

THIS book reflects an experience of thirty-two years as a specialist on the design and construction of conveying machinery, more especially as embodied in addresses delivered before several technical institutions and in certain articles contributed to the technical press.

No attempt has been made to write a complete treatise covering all classes of handling appliances, rivalling the late G. F. Zimmer's monumental work, "The Mechanical Handling and Storing of Material," to which frequent references have been made in the footnotes. Nevertheless many important types of conveying plant have been dealt with in a systematic manner; the text being amply illustrated by diagrams, scale drawings and photographs.

The present volume is not a compilation but an original practical work. It is in fact a record of first-hand experience, the writer himself having been responsible for the construction of many of the conveying plants described.

The book will be found helpful and suggestive to three classes of readers, viz.: (1) Directors and managers of large firms contemplating the installation of additional conveying plant; (2) factory and efficiency engineers advising on the layout and selection of such plant; (3) draughtsmen engaged in the detail designing of conveying machinery.

A long chapter describing numerous types of conveying chains and their application will be found particularly helpful to both designers and users of conveyors and elevators. At the end of the book there is an exceptionally full table of densities of bulk materials, progressively arranged in orderly sequence from the lightest to the heaviest substances of industrial interest. Finally, a comprehensive bibliography appended contains adequate references to many books, papers and technical articles of permanent interest and value to conveyor engineers.

From a study of the numerous examples of plants and details presented in the following pages, it will be realised that the design, construction and installation of conveying machinery collectively constitute an important branch of mechanical engineering; also one needing, for its successful prosecution, the intelligent application of scientific principles, coupled with much specialised knowledge and experience.

W. H. ATHERTON.

DERBY, ENGLAND.

CONTENTS

LIST OF PLATES

CONVEYING MACHINERY

CHAPTER I

INTRODUCTORY

All the means employed for moving goods from one point to another may be comprehended under two general heads, namely (1) *Intermittent* appliances (of which the wheelbarrow, crane and cage hoist are familiar examples), and (2) *Continuous* appliances, which include the numerous family of conveyors and elevators, also some types of ropeways.

In the most general sense one might include under the term " conveyor " any kind of truck, carriage, locomotive, canal boat, ship, crane, overhead runway, telpher, transporter or ropeway. But in the specialised technical sense here used a conveyor is a machine capable of carrying goods or material in a continuous stream and usually having, as its most characteristic feature, some form of endless band or a chain-belt, built up of a series of metallic links, together with its attached load carriers. Sometimes a series of light gravity rollers can be utilised instead of a power-driven belt.

It may reasonably be asked what is the precise distinction between a continuous elevator and a conveyor ? In reality there is no hard-and-fast line of demarcation between the two machines. Conventionally if the movement of the load is mainly *upward* or vertical the machine is called an elevator, whereas if the movement is mainly *along* or horizontal, the machine is styled a conveyor.

Expressed in geometrical terms one may conveniently say that if the vertical projection of the path of motion equals or exceeds the horizontal projection the machine is an *elevator*, otherwise it is a *conveyor*. Yet in practice the term conveyor is more comprehensive than the term elevator, even vertical elevators being often referred to as conveyors.

Actually the path of the load may be neither vertical nor horizontal, but inclined or curved or even wavy or zigzag. Some package elevators are arranged both to lift and to lower goods at pleasure. Other machines of similar type may only lower goods and are therefore styled " lowerers."

Some further technical terms which are freely used in conveyor engineering more or less indifferently according to the context and location are: assembly line, band, belt, carrier, chain, conductor, creeper, lattice and moving platform. Occasionally a bucket elevator is styled a " ladder."

Intermittent handling appliances like hoists are much older than conveyors. When the earlier London tube stations were built, moving stairways or escalators were quite unknown. Their advent from America a quarter of a century ago made cage hoists or lifts obsolete, or at least only a second-best method of moving passengers down to the trains and up again to the street. As long ago as 1913 the writer remarked[1] that escalators were much better than cage hoists, in which crowds of people were herded together; also that a large number of lift attendants could be dispensed with if moving stairways were adopted; and that less time would be wasted by passengers in waiting for the intermittently working lifts.

In a general engineering workshop (whether foundry, forge, machine shop, erecting shop or packing shop) the transportation work is essentially of an intermittent and miscellaneous character; demanding the use of overhead travelling cranes, pulley blocks and trucks. In such situations conveyors are seldom applicable; because they do not possess the same flexibility as cranes and they are not at all suitable for moving isolated heavy articles at considerable intervals of time.

Yet as mechanical engineering ceases to be less general and becomes more in the nature of manufacturing, so does the scope and applicability of conveyors widen. Jobbing shops are fast disappearing; the tendency being towards extreme specialisation, where an enormous number of mechanical details are produced in certain shops and assembled in others. Already conveyors are being effectively used in large foundries engaged on repetition work, whilst motor-car factories could hardly exist without an ample equipment of conveying machinery.

[1] *Transactions of the Manchester Association of Engineers*, session 1912-13, p. 355.

In large warehouses and productive factories the transport is of a fairly uniform and continuous character, the individual loads weighing pounds or hundredweights rather than tons, and the numbers being very great. Under such favourable conditions conveyors can be applied with great economic advantage.

Thus conveyors are essential items of works equipment, without which it would not be possible to maintain the required output of a factory or even to work on an economic basis at all. They are also a great aid in making repetition work easy and agreeable to the employees, who are often girls of slight physique.

In no industry is the application of labour-aiding appliances, for speeding-up output and increasing production, more amply justified than in the handling of coal on a large scale. Hence the adoption of mechanical systems of hauling, conveying, elevating, screening and washing coal has become universal in all modern well-equipped collieries. In the gas-making industry too, the enormous development and application of conveying machinery during the last fifty years has been remarkable. Nowadays no gasworks of any magnitude is complete without its equipment of coal and coke handling plants, whilst the mechanical conveyance of oxide of iron and of sulphate of ammonia is the established practice.

Although large fortunes are not made by engineers engaged in constructing conveying machinery, yet it certainly pays handsomely to use such machinery in a great variety of manufacturing operations. Great wealth has undoubtedly been amassed by utilising conveyors to the full in producing or handling vast quantities of such things as details of automobiles and bicycles; bricks and cement; sand and gravel; beer and mineral waters; bottled and canned foods; grain and flour; bread, biscuits and cakes; cattle foods; chemicals and artificial fertilisers; coal and coke; gas and electric appliances; proprietary foods and medicines; tea, milk and sugar; tobacco and cigarettes; chocolates and sweets; light textile goods; newspapers and packages; and many other articles, goods and products in daily use.

CHAPTER II

REASONS FOR USING CONVEYORS: TECHNICAL AND ECONOMIC

CONVEYORS are usually installed, after much consideration and discussion, for one or more of the following reasons :—

1. **To Save Labour and Time.**—Though economy of labour is always important, it is often of still greater importance to do the work more speedily and thus save time.

A conveyor is an automatic machine, the only attendance commonly required being to feed it with goods or material. Carrying goods about and trucking by hand labour are thus avoided, also the waste of time in coming back empty for new loads. Incidentally there is a general speeding-up of the factory to the carrying capacity of the machine, which sets the pace. Any negligence or slackness becomes at once apparent. In newspaper press-rooms the papers are poured out at such a rate from the machines that conveyors are essential to get rid of the papers fast enough to prevent congestion and to do it with the least possible labour. A similar remark applies to many other machines, such as automatic filling, weighing and labelling plant.

2. **To Increase the Output.**—With the aid of conveyors more work can be done on a given floor space, blocks are avoided and periodic or seasonal rushes of work can be got through with ease during ordinary working hours without resorting to overtime, as, for example, in bottling factories. Loss due to breakages is also reduced.

3. **To Utilise Existing Buildings for New Purposes.**—Conveying plant enables two or more detached buildings to be connected together and used for the same purpose or for several operations in proper sequence. One building may be old and the other new. The rooms may be at the same level or at different levels, and separated by a yard or a street or a railway. In this way old buildings can be utilised to

advantage and systems of working modernised without needless expense.

For example, a slat conveyor was erected to connect three old buildings, used as cold storage premises, separated by two streets in the heart of London. One of these buildings is situated on the bank of the Thames and is served directly by cranes unloading from barges various foodstuffs of a perishable nature. These goods (such as frozen carcasses of beef, mutton, rabbits, chickens, eggs and so forth) are placed upon the conveyor, pass over two streets and are received without further handling into either of the other two cold stores.

Thus the great utility of conveyors, in reducing costs of production and transport, has gradually come to be appreciated by makers on a large scale of many industrial products, also by storage and transport companies. It is seen that conveying plant has a marked effect in increasing the efficiency of productive factories by preventing waste of effort, time and money, also in promoting continuity of operation ; thereby eliminating expensive waiting periods, avoiding confusion and relieving congestion.

Costs.—A conveyor may cost anything from, say, £2 a foot of centres to possibly £20 a foot, according to its capacity and type. A complete unit with driving gear and supporting framing seldom costs less than £200 and rarely as much as £4000. Elevators are usually much shorter than conveyors and cost relatively more per foot of centres, the driving and tension terminals being expensive, while the middle part is comparatively simple and cheap. On a weight basis a rough estimate of cost is about £70 a ton, which is a low figure for machinery. But all costs tend to rise.

A complete materials-handling installation may consist of quite a number of different conveyors and elevators of various types and sizes, individually small but in the aggregate costing a large sum of money. For instance, in the year 1935 a new factory was built in East London for the preparation of cattle foods, the equipment including no less than 84 light conveyor units, the average cost of which was about £160 each.

Though the first cost of a plant is an important matter, it is not everything. Other things to be considered are reliability, efficiency, saving in labour and breakages, increase in output in the same space, cost of maintenance, power required to drive, and ease of obtaining renewals.

Conveying machinery is not installed unless it is certain to prove a very profitable investment of capital. In pre-war days it used to be estimated that a saving of one man justified a capital expenditure of £1000. Since 1914 labour rates have quite doubled, the biggest jump being in unskilled labour. Yet there would be great difficulty in persuading the average factory owner or manager to spend £2000 to save the labour of one man to-day. He would expect a conveying plant to pay for itself by the savings effected in, say, three years, and thereafter to be a clear gain, apart from upkeep.

Sometimes, indeed, the expenditure can be entirely wiped out in a single year or less by the saving in wages and the increased output due to the application of conveyors; but this favourable result must not be expected as a general thing. Depreciation varies from 5 to 10 per cent.

Even in the Far East, where Asiatic labour is still comparatively cheap, conveyors have become so efficient that they can handle materials on a large scale with greater expedition and economy than the cheapest of coolie labour.

Although the mechanical construction of individual conveyors is fairly simple, yet the variety of types is so great, and the conditions of application so diverse, that it often becomes quite a complex engineering problem to design the most suitable system of conveyors and elevators to satisfy existing local conditions and requirements. In this connexion the study of flow diagrams is helpful.

The designer also experiences the ever-present difficulty of reconciling as far as possible the conflicting demands of low first-cost on the one hand, and efficiency in operation throughout a reasonable period of years on the other hand. The desire on the part of many purchasers of plant to cut the price at all hazards is a mistaken policy, which often results in machinery that is cheap but not economical and sometimes leads to serious trouble.

Some practical guidance regarding the correct procedure in formulating inquiries and preparing proposals for conveying plants will be found in Chapter XV.

CHAPTER III

PACKAGE CONVEYORS FOR HORIZONTAL OR SLIGHTLY INCLINED MOVEMENT (CLASS A)

We now proceed to describe various forms of package conveyors as applied in different industries for handling bags, barrels, boxes, cartons, bottles, cans, rolls of cloth and so forth, with examples of each type of plant, suitable for the movement of goods in a variety of paths.

1. **The Wood Slat and Chain Conveyor,** lattice or moving platform, is the most useful and durable machine of this class for heavy duty. Slat conveyors are used largely to carry safely substances in bags, also general merchandise packed in boxes and crates, or made up in pieces and bales. They can be made partly horizontal and partly inclined, also with either a single or double strand of endless chain, to which are bolted a series of narrow boards or slats (usually from 1 to 1½ inches thick), thus forming a continuous travelling platform with slight gaps between the slats. The latter are preferably made of hard wood, commonly either beech or birch, planed to a smooth surface.

A complete conveyor also comprises one or two pairs of chain wheels, secured to the main and back shafts; the bearings of the latter sliding in slotted frames, in order to permit of the extension of the chain due to wear being taken up by tension screws from time to time. Cast-iron supporting rollers turned 8 or 9 inches diameter are provided at intervals of about 3 feet, the shafts often running in plain bearings fitted with Stauffer grease lubricators. Alternatively either ball or roller bearings may be used. The extra cost of such frictionless bearings is justified in long conveyors, since they reduce the power required to drive and also economise in lubricants and attention, as well as tending to cleanliness.

The slats are carried by a system of cast-iron rollers. The inner supporting rollers are plain, whereas the outer reliability, efficiency, saving in labour and breakages, increase in output in the same space, cost of maintenance, power required to drive, and ease of obtaining renewals.

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The slats are carried by a system of cast-iron rollers. The inner supporting rollers are plain, whereas the outer rollers have guide flanges to prevent wandering. Both the top and bottom roller shaft bearings are usually bolted to continuous steel channels. The source of power is usually an electric motor, driving through a train of reducing gearing, the main shaft making only about 8 revolutions per minute. Some factory engineers like enclosed worm reducing gears, whilst others prefer to have the gearing fully exposed to view though guarded. Details of drives are studied in Chapter XIII.

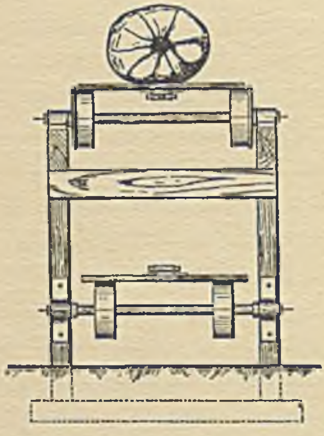


FIG. 1.—Section of Slat Conveyor for Sacks.

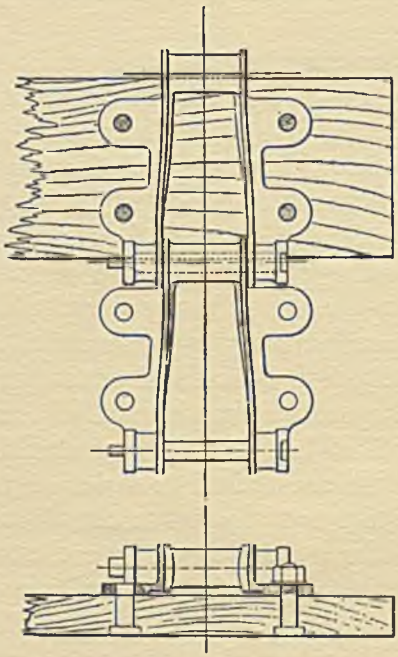


FIG. 2.—Detail of Pin Chain and Wood Slat.

Fig. 1 shows in cross-section a wood slat conveyor handling 2-cwt. bags or sacks of sulphate of ammonia at a chemical works; the centres (length between the end shafts) being 240 feet and the slats 24 inches long by $5\frac{3}{4}$ inches wide. In this instance the framing is made of wood, which is relatively cheap as well as resistant to acid fumes; though steel framing is now more usual.

Down the centre of the bagging shed or store runs the slat conveyor, at a speed of 50 feet per minute, just below floor-level. When a Thames barge comes alongside the wharf, the bags of sulphate are quickly fed on to the conveyor by small hand trucks. They then pass through the wall, travel some distance across an open yard and are delivered in a constant stream down a chute into the barge.

The conveying capacity is fully 600 bags per hour. Near the driving terminal is fixed a swinging flap, and a counter connected therewith automatically records the number of sacks passed into the barge. This counter is kept under lock and key, forming a perfectly reliable sales record.[1]

Fig. 2 shows the chain successfully used on this conveyor, its reference number being No. 500 K2. It is a Gray type [2] pin chain of 6-inch pitch. The joint pin is held securely against rotation by a T-head and has a large bearing area. The pin is made of high carbon steel and the link proper of Ley's blackheart malleable iron, thoroughly annealed.

This material is peculiarly suitable for conveyor chains, as it can be cast readily into the most complicated forms of attachment links, and it does not easily corrode. This particular chain has continuous attachments or lugs, by means of which each link is well secured to each slat by four $\frac{1}{2}$-inch bolts. To shorten the chain it is a simple matter to take out a few links and then to readjust the sliding bearings of the back shaft.

In another design of slat conveyor (Fig. 3) the ends of the slats are furnished with brackets and flanged rollers of small diameter, running on angle-iron tracks. Alternatively a roller-chain with **A**-type attachments may be bolted to each end of the slat. The slats need not necessarily be fitted close together, but can be spaced a foot or more apart in some cases. This design avoids the slight up-and-down movement of the load in passing over fixed supporting rollers due to the sag of the chain, which is an advantage. Also it is easy to add top roller guides to prevent lifting at a bend. On the other hand there is more difficulty in lubricating numerous little rollers than fixed bearings, and they are certainly less secure and durable. Moreover, rollers revolving in contact with wood slats are rather quieter in working than cast-iron rollers running on angle-iron tracks.

[1] Automatic counters controlled by photo-electric relays are now also available and find increasing application in mass-production factories.

[2] See Chapter VIII on Chains.

Fig. 4 shows in section a noteworthy slat conveyor[1] of 470 feet centres, moving 2-cwt. bags of granulated sugar from the warehouse to the wharf at a large sugar refinery, Silvertown. It is driven by a 20 H.P. 3-phase motor at a speed of 70 feet per minute, the motor having an ample margin of power. In this case the hard wood slats are 30 inches long and are bolted to *two* strands of No. 500 K2 chain, the latter having a life of twenty years on this duty.

The main lattice steel girders of the conveyor bridge or gantry are 7 feet 6 inches deep, and are supported in four spans 20 feet above the yard level by lattice steel towers and

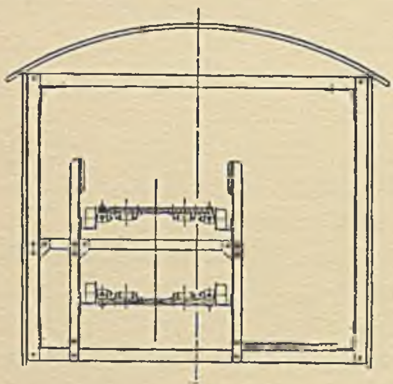


FIG. 3.—Section of Conveyor with Roller Slats.

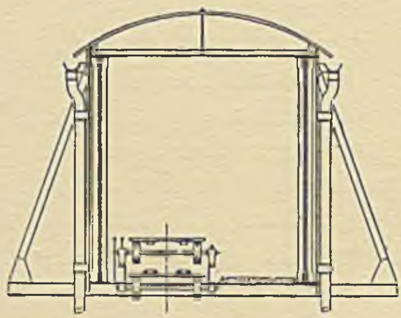


FIG. 4.—Double-strand Fixed Roller Bag Conveyor and Gantry.

cross girders. The longest span in the gantry is 133 feet and the height 37 feet to the top of the cross girders, from which the main girders are suspended.

The positions of the towers were fixed by inflexible local requirements, owing to an old ropeway having to be cleared as well as several sets of metals on which railway trucks were continually being shunted about.

Several successful slat conveyors, with additional central supporting rollers between the chains, have been constructed for similar duty. Plate II depicts twin conveyors of about 800 feet centres, fitted with 30-inch beech slats bolted to double-strand Ley bushed chain (No. 600) running on 9-inch turned cast-iron supporting rollers, the guide rollers being

[1] An elevation of this sugar-bag conveyor is given in my Manchester paper on Package Conveyors of 1913.

flanged. The bags of sugar (chiefly 2 cwt.) are discharged down swivelling delivery chutes fitted with brakes.

These conveyors are carried in an elevated steel gantry 6 feet 6 inches deep, covered with asbestos corrugated sheets; supported by lattice-braced trusses, plated cross beams and trestles, and by a steel tower at the delivery end containing the driving gear.

Each conveyor is driven by a 15 H.P. slip-ring motor, through a fluid coupling, belt and cut spur reduction gearing. The speed of the conveyor is rapidly varied from zero up to 60 feet per minute by a servo-motor pumping oil into its Vulcan-Sinclair coupling, which is operated by a tiny lever fixed at the foot of the delivery chute.

From three floors of the warehouse 1 and 2 cwt. bags of sugar are fed on to these conveyors by an inclined slat elevator; whilst from one floor only cases and cartons of syrup are also fed on to the same conveyors by a short humper or crossbar type of conveyor, as shown in Fig. 11. The total cost of this fine conveying plant was approximately £16,000, excluding foundations and builders' work.

A single-chain slat conveyor, when fitted with a biflex or biplanar or universal chain, can take packages round corners and in an undulating path, as in the example shown in Plate III. This feature gives great flexibility and adaptability to suit the peculiarities of the site; the path being no longer restricted to motion in one plane only, as it is in the case of either a double-strand slat conveyor or a belt conveyor.

2. **Double-service Slat and Chain Conveyor.**—The special feature of this type is that the return strand of chain, instead of returning empty below the top strand, travels in the opposite direction alongside, so that both sides can be utilised for carrying material (see Fig. 5). The terminal shafts are usually vertical, though occasionally inclined to accommodate sloping ends. This double-service feature is specially useful when moving open crates, bottles, jars, tins and other goods needing careful handling. If the articles are not taken off they simply go round the circuit again and cannot be thrown off on reaching a terminal.

When a double-service conveyor is horizontal a suitable Ewart chain for carrying the slats is No. 79, of 5¼-inch pitch, fitted with G20 type attachments. The wood slats are often shaped or tapered to accommodate the end-wheels, instead of being made rectangular and separated by wide gaps. This is seen in the photographic view (Plate II) of the driving end of a conveyor in the packing room of a floor-polish factory. In

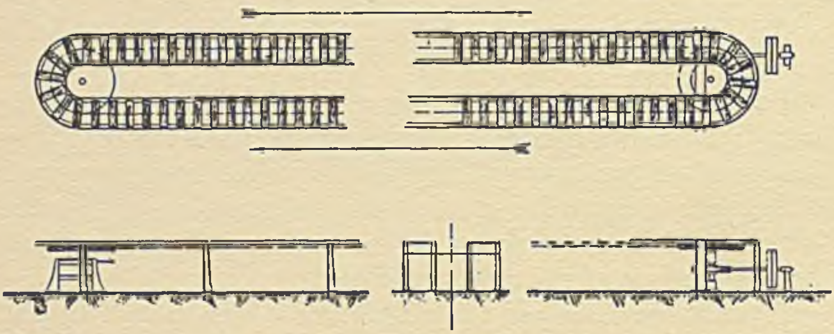


FIG. 5.—Plan and Elevation of Double-service Slat Conveyor.

the small bottle carriers so largely used in bottling stores and dairies, the slats are cast integral with the chain links, either in malleable iron or in bronze.

Fig. 6 indicates the layout of a double-service conveyor installed in a Manchester bottling store.[1] An unusual feature in this case is the loop standing out at right angles to the main body of the conveyor. The chain used is the Dodge cable

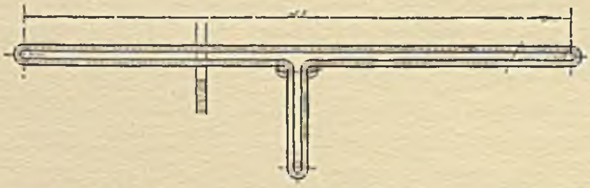


FIG. 6.—Diagram of Looped Double-service Conveyor.

type with renewable malleable-iron bearing blocks. This chain, being flexible in two planes at right angles to each other, is not compelled to move in a horizontal path. Thus the direction of motion may be partly horizontal and partly inclined, the axes of the terminal shafts being set accordingly.

Double-service conveyors take up a lot of room and they

[1] Photographic views are given in Zimmer's book, vol. i, p. 195, and in my 1913 paper.

have partly gone out of fashion since overhead monorail conveyors came into general use. The latter are both cheaper and more economical of floor space, but they are less easy to load and unload. Yet both types have found extensive application in grey-iron foundries producing large numbers of similar castings.

Monorail conveyors, when fitted with biflex or universal chain, are eminently adaptable to a complex layout in factories engaged on light repetition work, such as bicycles. Their great flexibility and low cost have also made them extremely popular in large motor car-factories (see p. 44).

3. **Cotton Band or Belt Conveyors** are used for carrying baskets, bags and pieces of cloth, also cartons and light packages free from nails and hoop iron, which are liable to cut the band. They are relatively cheap in capital cost, also easy to drive and quiet in operation, the last feature being sometimes of special importance. Yet band conveyors are less suitable and durable than chain and slat conveyors for handling heavy bags, cases and crates. Bands stretch more than chains and are not so easy to shorten.

It is important to have the terminal drums or pulleys of large diameter, especially when the belt is a stiff one ; otherwise the tension has to be heavy or slipping takes place and the life of the belt is short. Besides plain cotton belts, bands made of balata and of canvas embedded in a rubber jacket are also successfully employed. But these stiffer belts are more used for carrying coal and other material in bulk than for packages. Woven wire belts are also employed to a limited extent for bags and cases.

Many band conveyors have been installed for moving letters and parcels at various large post offices. Figs. 7 and 8 and Plate V depict in cross-section, side elevation and perspective respectively, a pair of bands for carrying mail bags and baskets at a Liverpool parcels sorting office, at a speed of 120 feet per minute. These conveyors are 30 feet centres by 3 feet wide, inclined at an angle of 10 degrees. The bands are five-ply cotton, the joints being made by two cover strips of leather. The cast-iron end-drums are 15 inches diameter and the deflecting rollers 9 inches diameter, with gravity tension gear. All these details might perhaps have been made larger with advantage to the belt.

Each conveyor is driven by a $2\frac{1}{2}$ H.P. motor through a worm-reducing gear and a chain drive. The belt-supporting rollers or idlers are 4 inches diameter at 30-inch pitch, made of solid-drawn steel tubing, turned all over and fitted with through shafts running in ring-oiling bearings. There are deep steel-

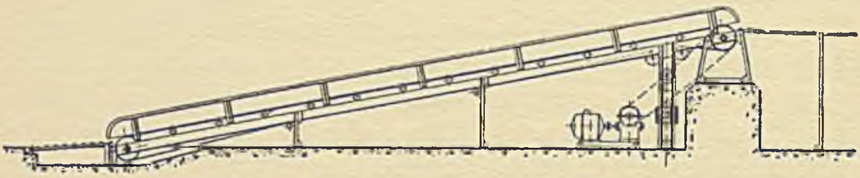


Fig. 7.—Side Elevation of Band Conveyor for Parcels.

plate guides for the packages. The basket conveyor only has light steel feeding rollers $2\frac{1}{2}$ inches diameter at each end, running in ball-bearings. The bands are reversible, being used for both inward and outward service. At this office the Canadian traffic is very heavy and must be dealt with expeditiously; *time* being here the most important factor.

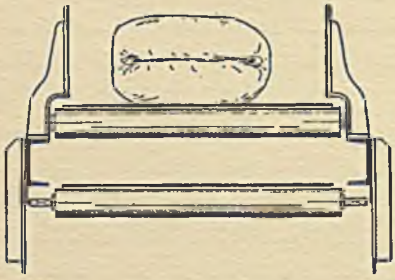


Fig. 8.—Cross-section of Band Conveyor for Parcels.

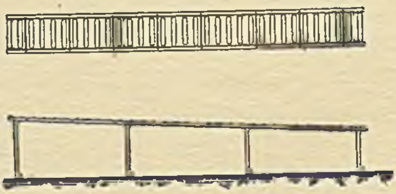


Fig. 9.—Gravity Roller Runway.

4. **Roller Runways.**—The gravity conveyor or slightly inclined roller runway (Fig. 9) is much used for moving boxes of regular shape having smooth bottoms.[1] As auxiliary appliances these runways are easy to apply and very convenient. Their attractiveness lies in their cheapness and in their applicability where neither running shafting nor electric power is available. Yet the carrying capacity of a roller runway is much less than that of a continuous power-driven conveyor. and the useful length is limited.

[1] See Zimmer's "Mechanical Handling," vol. i, p. 196, for a good example.

In addition to their extensive application in bottling stores and mineral water factories, gravity conveyors are useful and adaptable in any factory where large numbers of boxes, cases, cartons and bags have to be moved through comparatively short distances ; as in the soap, sugar, syrup and confectionery industries. By utilising switches and taper rollers it is easy to negotiate fairly sharp bends and sinuosities. The facility with which roller runways can be led round curves is one of their best features. Spiral lowering chutes composed of light taper rollers fitted with ball-bearings are also successfully employed.

In the case of an ordinary chute of wood or steel plate, there is considerable friction between the sliding body and the surface of the chute. A roller runway is an artifice to reduce friction to a minimum, by substituting freely revolving rollers for the chute bottom. In this way the gradient can be reduced to about 1 in 20, or 5 degrees. Thus a runway 100 feet long must have the feeding end about 5 feet higher than the delivery end, a condition that is not always admissible. Bags and cartons demand steeper gradients than do smooth boxes.

Formerly the rollers were made of hard wood, with plain spindles running in holes drilled in a supporting angle-iron. Then pivot-bearings were used along with fairly thick solid drawn steel tubes 3 inches diameter. Later much lighter steel rollers, about 2 inches diameter, became common, fitted with light ball-bearings running on fixed spindles. For conveying bags it is necessary to use rollers of very small diameter ($1\frac{1}{2}$ inches) set at close pitch ($1\frac{3}{4}$ inches), otherwise the bags hold up. Light steel rollers are prone to become extremely noisy in operation and they are not durable, being easily dinted and bent out of shape and balance. In a dusty atmosphere the ball-bearings soon give trouble, and the rollers then refuse to rotate freely.

In order to avoid the rather heavy physical labour of feeding a gravity conveyor by hand, a power-driven inclined chain conveyor (sometimes styled a " humper ") is often applied in combination therewith, an example being given in Fig. 10. This shows a double-strand conveyor with round crossbars, which push up the bottled beer boxes on a series of light steel rollers, the conveyor itself being driven by a small electric motor. After arriving at the top the boxes complete their journey of 110 feet by gravity. The finger-tray type of vertical chain elevator is also very often used in

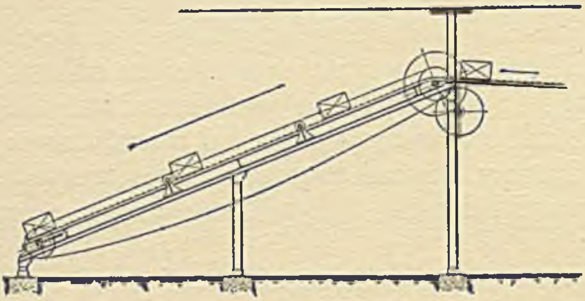


FIG. 10.—Inclined Conveyor Feeding Roller Runway.

conjunction with roller runways, both at the feeding point and at the delivery point.

Fig. 11 indicates in principle a recent example of a humper for feeding cases of syrup on to a pair of long slat conveyors through a curved roller runway. This humper is a specially

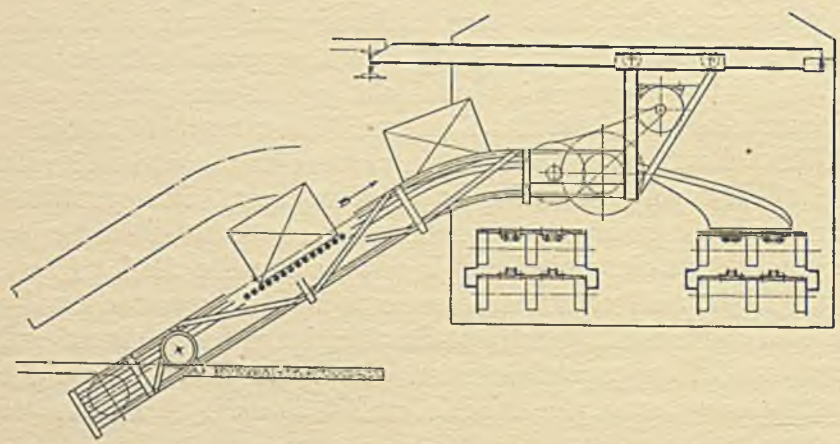
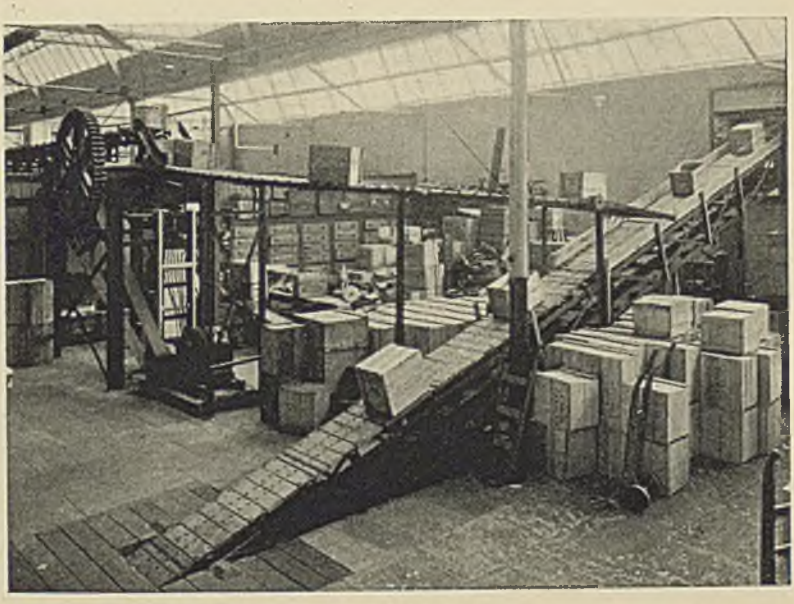


FIG. 11.—Humper Feeding Cases to Twin Slat Conveyors.

designed self-contained unit which is capable of being moved bodily on its supporting wheels into either of the two positions needed for serving the twin slat conveyors with cases. Its advent solved a perplexing problem in a simple yet perfectly successful manner.

30-inch Slat Conveyor Gantry for Sugar.



18-inch Slat Conveyor in Soap Factory.

[To face page 16.

PLATE II

30-INCH TWIN SLAT CONVEYORS FOR SUGAR.

DOUBLE-SERVICE CONVEYOR IN FLOOR-POLISH FACTORY.

To face page 17.]

CHAPTER IV

PACKAGE CONVEYORS FOR VERTICAL OR STEEPLY INCLINED MOVEMENT (CLASS B)

1. **Rigid Arm Elevators.**—Fig. 12 shows a simple and effective type of continuous elevator or conveyor which is extensively applied to the lifting of bags, bundles and barrels,

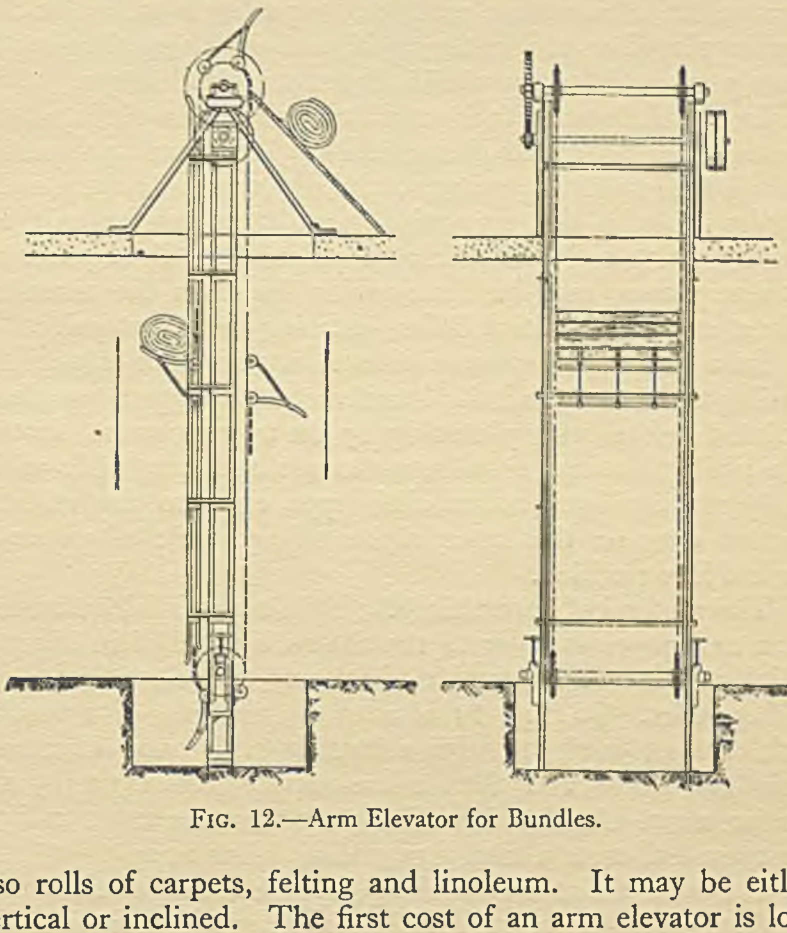


FIG. 12.—Arm Elevator for Bundles.

also rolls of carpets, felting and linoleum. It may be either vertical or inclined. The first cost of an arm elevator is low, the space occupied small and the power absorbed insignificant, whilst the saving in labour is enormous. Plate IV clearly depicts its application for lifting rolls of roofing felt, a loading grid being utilised to support the roll at the bottom, and an inclined chute to receive it at the top as the carrier arms tip over. For some details of this elevator, see Table I, column B, page 20.

An arm elevator consists of two strands of chain running over two top and two bottom wheels of small diameter, together with the necessary shafts, bearings, reducing gear and framing, plus a source of power. Fastened to the chains, at intervals of from 5 to 10 feet, are projecting arms and struts, made either flat or curved to suit the packages to be raised, whether forming a pile of newspapers or a roll of felt or a cask. These arms pick up the packages as fast as they can be placed on the loading grid, and discharge them as the arms pass over the top wheels, if not removed sooner.

In cloth elevators it is usual to bolt to the chain attachments a few wood slats above each carrier, in order to protect the cloth from being soiled, especially at the delivery point. Obviously, with this type of elevator there can be only one loading point and one discharge point; but light packages, as newspapers, may be removed by hand on the ascending side at any floor or stage before reaching the top wheel.

In a newspaper elevator a necessary addition is a slotted loading table, on which the bundles of loose papers are placed by hand before being picked up by the moving arms. Instead of a plain plate it is even better to use a loading table of the freely moving light endless chain type, so as to eliminate the friction drag on the lower sheets when a pile of papers is pushed into position.

The method of connecting the light malleable-iron carriers on a newspaper elevator to the chains is detailed in Fig. 13, which also shows the carrier of a heavy cask elevator as used in breweries. In Fig. 14 is seen an example of a vertical cask elevator equipped with a loading grid, upon which the casks are rolled and then automatically picked up by the carrier arms. At the top of the elevator the casks roll off the arms and on to a discharge grid and then away.

The arm elevator is a cheap, compact and efficient type of labour-aiding machine, which is so simple in its mechanical details as to be practically foolproof. The running-gear being

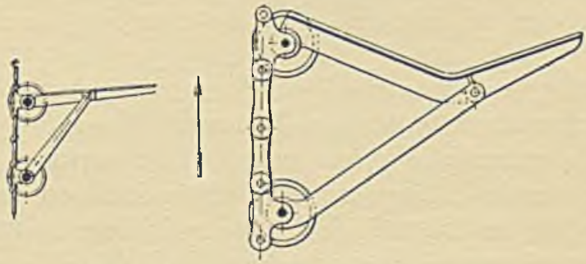


FIG. 13.—Light and Heavy Carriers.

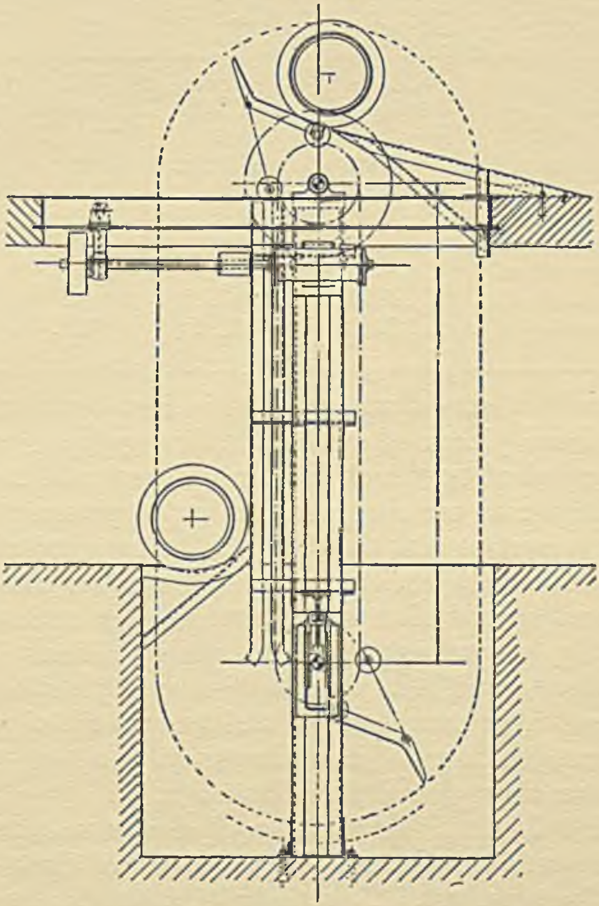


FIG. 14.—Cask Elevator with Loading Grid.

perfectly balanced and the speed slow, the power absorbed in lifting a series of loads is often so small as to be almost negligible.

Arm elevators are usually rather short, being generally used to connect a basement to the ground floor, but they have been made exceptionally up to 100 feet centres. Though commonly vertical, they are also made inclined to suit the site. Certain useful technical data referring to four actual vertical arm elevators are summarised in Table I.

TABLE I.—ARM ELEVATORS

	A	B	C	D
Ref. Index	Bir. Post.	Anderson	Anglo Am.	Stretton
Goods lifted	Newspapers	Felt rolls	Oil casks	Beer casks
Pitch of carriers	4 ft.	10 ft.	7·5 ft.	10 ft.
Speed per minute	40 ft.	45 ft.	40 ft.	35 ft.
Loads per hour	600	270	320	210
Shaft centres	17 ft.	10 ft.	24 ft.	13 ft.
Ley's chain used	No. 57	No. 578	No. 500	No. 555
Diam. of top wheel	10·5 in.	20 in.	18 in.	20 in.
Diam. of top shaft	1·5 in.	2·5 in.	3 in.	3·5 in.
Power of motor	1 H.P.	$1\frac{1}{2}$ H.P.	4 H.P.	4 H.P.

The inclined arm elevator shown in Fig. 15 is suitable for handling loose pieces of cloth in finishing factories; wood slats being bolted to the chains for a distance of 2 or 3 feet above each set of carrying arms, so as to prevent the cloth coming into contact with the chains and getting soiled. When the inclination does not exceed 45 degrees the arms can be omitted and special slats substituted, either at intervals or continuously, to prevent the load sliding down. Such an inclined elevator with continuous V-shaped slats has proved very successful for transferring 1 and 2 cwt. bags of granulated sugar from three floors of a warehouse on to a long horizontal slat conveyor through a short roller chute.

Occasionally it is required to discharge automatically a stream of goods on the ascending side of an elevator before reaching the top shaft. This tricky problem has been solved by the ingenious artifice shown in Fig. 16, indicating the transfer of bales of paper pulp from an arm elevator to a slat conveyor. The top wheels are made of relatively large diameter, and chain-deflecting wheels are introduced with the object of canting the carrier arms sufficiently for the load to slide off the arms on reaching the required discharge level. The same principle has been applied to a timber log elevator at a match factory and to a round steel-bar elevator at an engineering works (see Fig. 17). The bars, 3 inches diameter

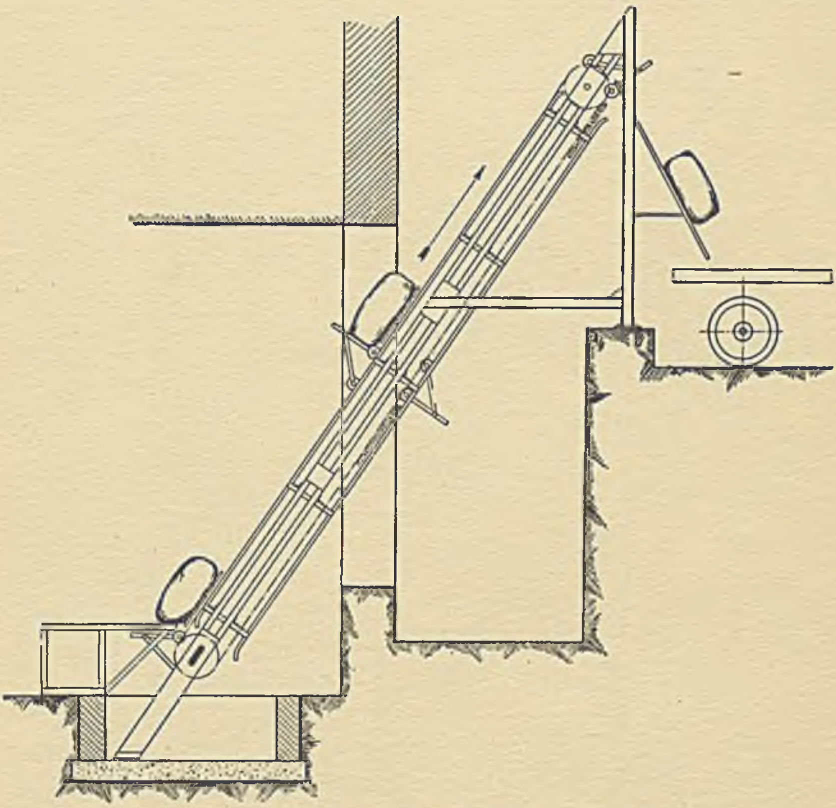


Fig. 15.—Inclined Arm Elevator for Cloth Pieces.

and 12 feet long, are raised from the basement stores to the machine shop on the floor above. This design is compact and effective.

The arm elevator clearly has its limitations, since it is unsuitable for serving several floors and for lifting breakable goods. It is essentially a single-purpose machine rather than a machine of general utility like a cage hoist, which will take anything that comes along. It is a case of one machine for one job. This job it does marvellously well; but troubles begin as soon as you try to handle a miscellaneous variety of loads of different shapes, sizes and weights.

In a recent example of an arm elevator, noteworthy for its exceptional height of 100 feet centres, raising 40-pound bundles of empty sugar bags, the chains (No. 503 of 3-inch pitch) are deflected just below the top wheels by means of

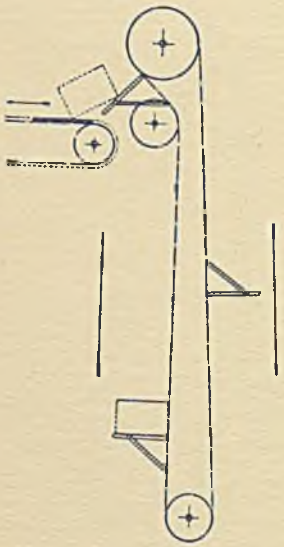


Fig. 16.—Discharge of Load on Rising Side.

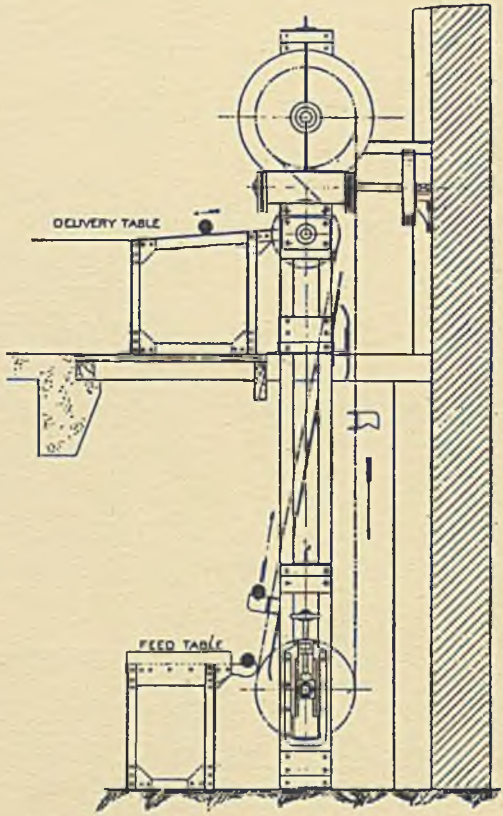


Fig. 17.—Elevator Lifting Long Steel Bars.

curved guides on the falling side. The object of this is to permit of a more ample discharge chute for the bags and to reduce the width of the steel casing, the space available being rather restricted. At a chain speed of 60 feet per minute and carriers 5 feet apart, the capacity is 12 bundles per minute or 720 per hour.

2. The **Crossbar** type of steeply inclined bag elevator is indicated in transverse section by Fig. 18. This form of

elevator is not so nearly foolproof as the inclined slat elevator, but it occupies less floor space and has the advantage of multiple-point delivery.

After the bags have been filled with, say, cattle food, weighed and sewn up, they are placed nearly upright on a tiny loading stage. A tubular crossbar secured to two chains then picks up the bag, which slides lightly in contact with wood guides as it is pushed up to the delivery point. Delivery of the bag may take place at the top of the elevator or at an intermediate floor ; as the crossbar elevator is made suitable for discharging bags on the rising side at any floor by

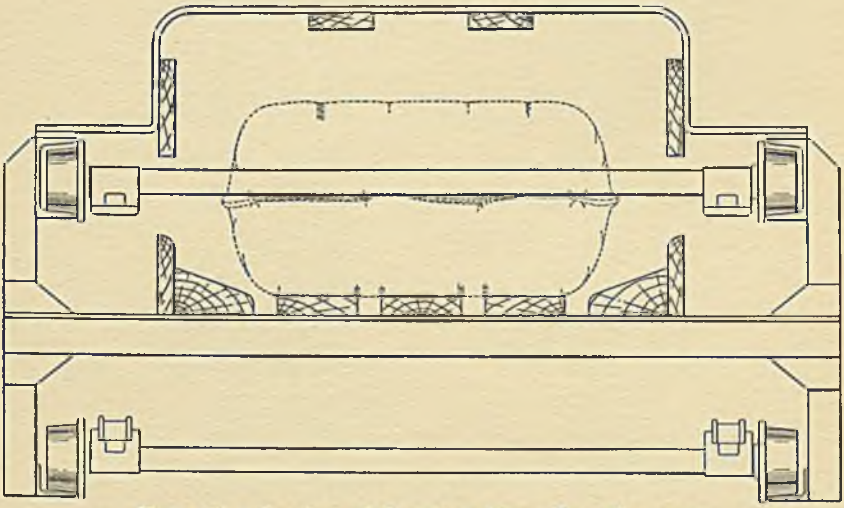


Fig. 18.—Section of Crossbar Type Bag Elevator.

arranging a series of either hinged or sliding discharge doors. When a bag leaves its straight-line path it drops through the first door that remains open, passes between the return chains and falls on to the desired reception floor.

When the bags are delivered over the top wheels, it is most important that the delivery chute be made steep enough to ensure their free discharge ; for if a bag should hold up, instead of falling clear, it will be trapped by the next crossbar and a jam or breakdown will result. It is therefore advisable to fit either a safety slipping device or a shear pin.

3. **Simple Swing-tray Elevator.**—This type of elevator is of more general utility than the crossbar type, since it is well adapted for lifting and lowering goods in bottles, cans,

crates, baskets or other containers through any required number of floors in lofty warehouses. Some of these goods would, of course, suffer injury if discharged upside down from an arm elevator.

As seen in Fig. 19, the running gear of a light swing-tray elevator comprises a series of flat-bottomed trays or carriers

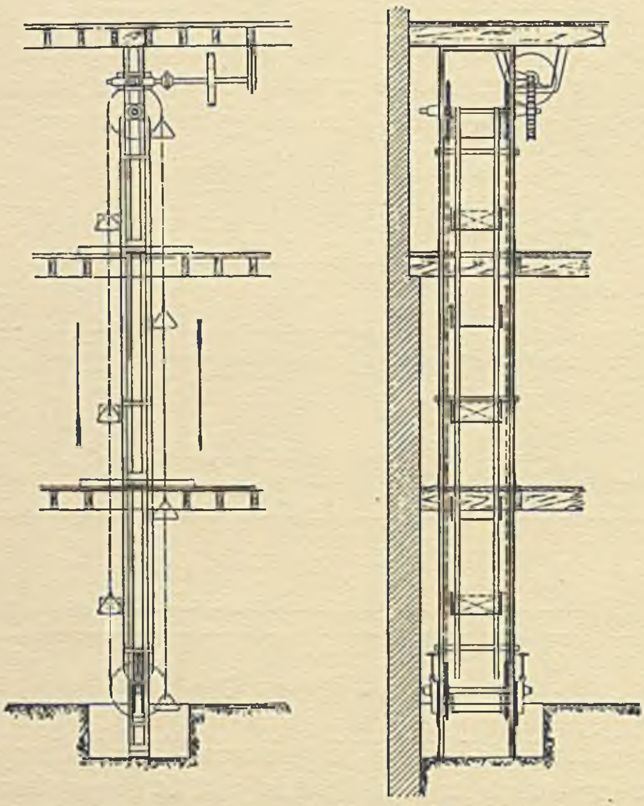


FIG. 19.—Light Swing-tray Elevator.

freely pivoted to two strands of Ewart chain by studs and **D**-type link attachments ; the chains engaging with two pairs of wheels of rather large diameter secured to the terminal shafts. The top shaft runs in fixed bearings, whilst the chain tension gear is arranged at the foot of the elevator. The swing-trays are often made of malleable iron triangular end-slings, connected by cross angles, to which are bolted wood battens. Vertical guides are desirable, to eliminate the oscillations of the swing-trays, when the load is being either put on or removed by hand. Corner guides are seen in the diagram (Fig. 20), which shows in part plan view not only the simple form of swing-tray but also the skeleton type of carrier that can be adapted for the automatic pick-up and discharge of heavier packages. Observe that the latter design has two central guides which limit the swings of the carrier to a negligible amount.

The packages are generally loaded on the ascending side;

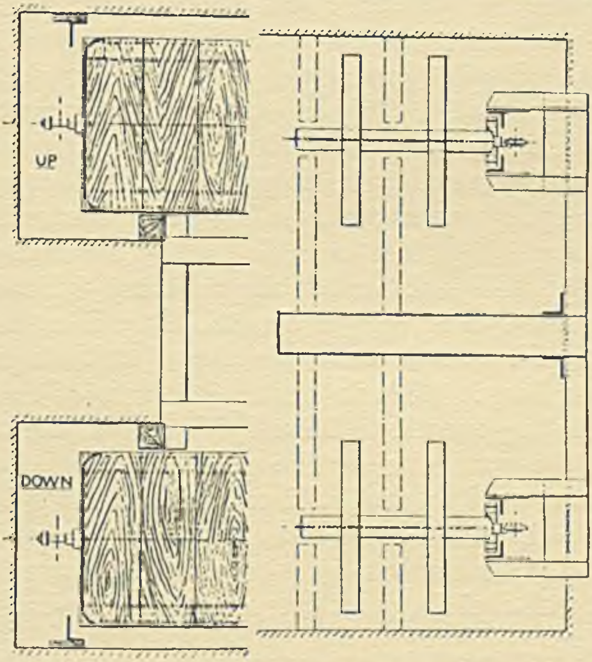


FIG. 20.—Part Plan View of Swing-tray; also of a Fingered Carrier.

and they can be removed from either the rising or the falling trays as may be most convenient. If the packages are missed no harm is done, as they simply go round the circuit again. This is a feature of considerable importance and convenience.

As the centre of gravity of the loaded swing-trays is kept well below the axis of suspension, their position is normally maintained horizontal when they pass round the terminal wheels. But any stiffness at the pivot pins would be fatal; also careless irregular loading might cause the trays to cant to a dangerous extent when clear of the guides. Then a breakable package might be dropped through six floors with disastrous results. Such things have actually happened on extremely rare occasions. But there are ways and means of avoiding these accidents. However, one can justly say that a swing-tray elevator of the simplest type is less nearly fool-proof than either an arm elevator or a slat elevator, though it possesses some good features which they lack.

A certain amount of fencing is desirable from a safety point of view round each floor opening through which an elevator passes. Expanded metal guards suffice in many cases, in others the entire elevator is enclosed within a sheet-steel housing, fitted with vertically sliding doors at the points of loading and discharge. Where floor space is very restricted and existing machinery has to be avoided, it is sometimes necessary to crank an elevator in order to get it in the space available.[1]

The carrying capacity of a swing-tray elevator is governed by the rate at which it is possible to feed the loads on to the moving trays by hand. When the trays are 4 feet apart, and the chain speed is 1 foot per second, there is a time interval for loading of 4 seconds and a capacity of 15 loads per minute, or 900 per hour. This is about the limit of feasibility as regards working capacity. Should this rate of working be too great for the particular service required, then the distance apart of the carriers can be increased or the speed of the chain reduced. A moderate speed is 40 feet per minute.

Table II summarises in a convenient form the more important technical details of four selected swing-tray elevators.

TABLE II—SWING-TRAY ELEVATORS

	A	B	C	D
Ref. Index . .	Holmes	Cope	Bovril	Borro's
Goods lifted . .	Paint cans	Cigarettes	Extract	Drugs
Pitch of carriers .	10 ft.	10 ft.	9 ft.	10 ft.
Speed per minute .	41 ft.	40 ft.	40 ft.	40 ft.
Loads per hour .	246	240	267	240
Shaft centres . .	29 ft.	42 ft.	32 ft.	62 ft.
Ley's chain used .	No. 57	No. 79	No. 79	No. 503
Diam. of top wheel .	24 in.	30 in.	30 in.	48 in.
Diam. of top shaft .	2·5 in.	2·5 in.	2·5 in.	3 in.
Power of motor .	1 H.P.	2 H.P.	3 H.P.	5 H.P.

[1] See Zimmer's "Mechanical Handling," vol. i, p. 35, and my 1913 Manchester paper.

Naturally, the actual rate of working depends a good deal on the size and weight of the packages forming the load; the best results being obtained when handling small loads of nearly uniform size and weight. Skips full of cotton cops or bobbins weighing 90 pounds, however, can be handled quite easily at the rate of three a minute, even by young lads, when using suitable loading tables; from which the skips are slid on to the slowly ascending swing-trays without being lifted bodily, and slid off the trays at the various unloading points.

The power needed to drive a swing-tray elevator is surprisingly small. Frequently a motor of only 1 H.P. is sufficient, and a large elevator serving seven floors of a warehouse is easily driven by a 5 H.P. motor when handling a steady stream of goods. This economy of power is due to the machine being perfectly balanced, coupled with the slow speed of the main shafts, and the uniform motion of the moving parts. In cage hoists, on the contrary, there is a serious absorption of power in overcoming the inertia of the cage and the load, plus the balance weights, during the period of acceleration after every stoppage.

Swing-tray elevators are best driven at the top, and the tension screws placed at the bottom. Then, if the chains are allowed to become slack, their own weight will maintain contact with the top wheels. Also the load on the shaft-bearings is then a minimum, because the chain is tight on the rising side and slack on the falling side. On the other hand, when the drive is at the bottom the chain is tight all round the circuit, and the load on the top shaft is thereby greatly increased. In some rare exceptions elevators are driven at the bottom when power is not available on the top floor, but the chain must then be kept taut.

It is important that the chains used for elevators should be of ample strength and bearing surface, also provided with suitable attachments for the reception of the pivoted carriers or swing-trays. For light elevators the Ewart or pinless detachable chain is commonly employed, while for heavy duty the Gray pin-chain is stronger and more suitable. The precise method of connecting the sling to the chain, in three examples (light, medium and heavy), is clearly shown in Fig. 21, using standardised chains.

A swing-tray elevator when properly made and used is a reliable, speedy and economical machine for lifting large quantities of packages; but trouble may be expected if the goods are tumbled into it anyhow, reasonable care being necessary in placing the packages on the carriers.

Nevertheless an ordinary cage hoist or lift is more suitable when the packages are few in number, very bulky, and of all possible shapes and sizes. Also a lift shows up better when it is required for occasional passenger service as well as for goods, or when it is necessary to run loaded hand-trucks right into the cage.

While swing-tray elevators are not of universal application, they are used successfully even for passenger service in some

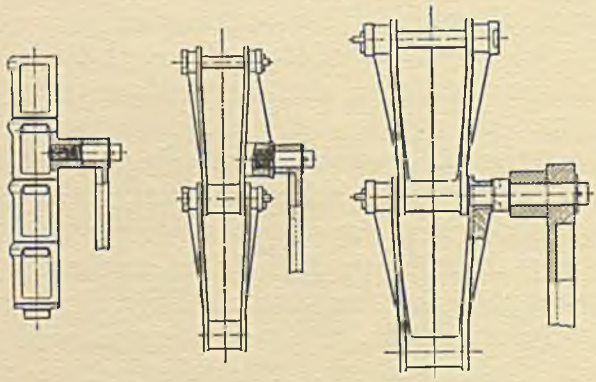


FIG. 21.—Detail of Sling Connections for Various Chains.

high office buildings. In the city of Hamburg the writer has made several " circular tours " on these so-called " Paternoster Aufzuge " ; travelling safely upwards in an open-fronted cage, over the top wheels and then down again below the bottom wheels. No attendant is required.

Although the standard swing-tray elevator has always two endless chains, between which the loads are suspended, yet elevators with only a single chain are occasionally made for light duty. Fig. 22 indicates such an exceptional example with overhanging trays, this type being sometimes styled a face-plate elevator; though it is used for both raising and lowering goods through a series of floors. This design is economical of floor space.

4. **An Anti-tipping Device.**—In referring to the simple

swing-tray elevator, it was pointed out that there is a certain critical unguarded period, after the carriers have left the vertical guides and are going round the top wheels, when the force of gravity alone is available for keeping the carrier

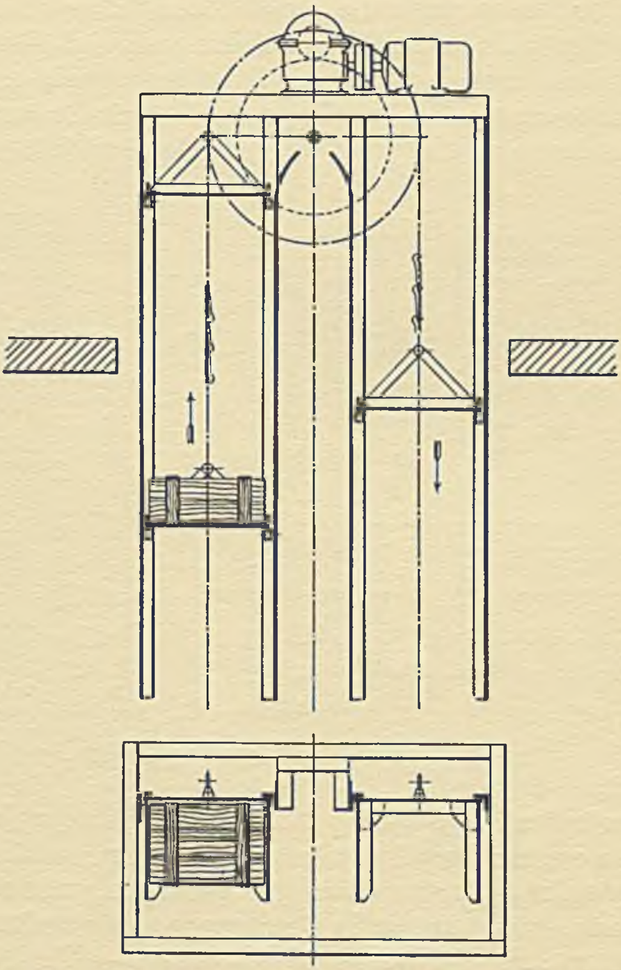


FIG. 22.—Face-plate Elevator with Single Chain.

in a stable position. Hence in the event of really bad casual loading of any carrier, or even if there is lack of freedom at a pivot pin, there is some danger of the whole carrier being canted to such an extent that its load may slip off and fall down.

In order to prevent this happening a special anti-tipping device has been devised by R. M. Williams, which has been jointly patented by him and the Ewart Chainbelt Co. Ltd. The device is fully described in patent specification No. 415,567 of the year 1934.

This anti-tipping gear is adapted to both swing-tray elevators and conveyors, the general idea being clearly indicated in Fig. 23. It will be seen that each end-sling has an extended arm carrying two small guide wheels or rollers, which travel on two intersecting curved tracks in such a way that the rollers and the pivot pin provide a stable three-point

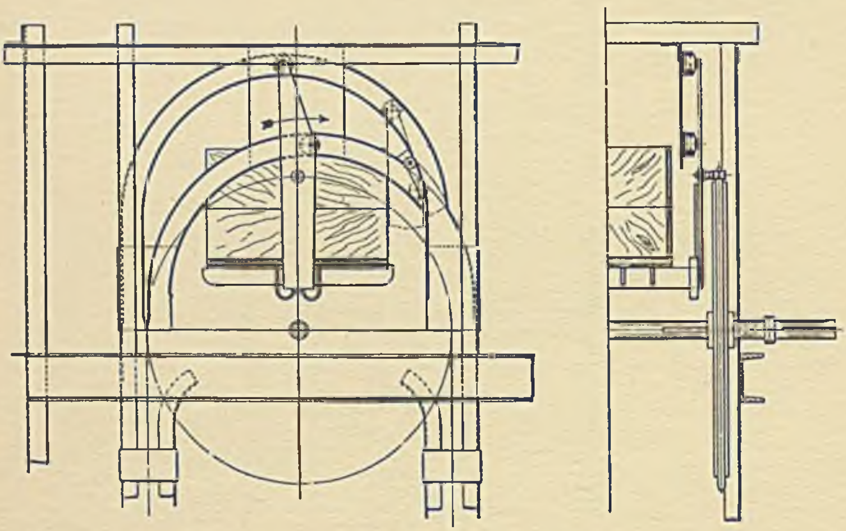


FIG. 23.—Anti-tipping Device for Elevator.

contact or suspension. Thus it is not possible for the carrier to tilt, no matter how irregularly it may be loaded : hence it is very suitable for an elevator handling a great variety of miscellaneous packages, as in a railway goods warehouse.

5. **Automatic Finger-tray Elevator.** — The ordinary swing-tray elevator has certain limitations coupled with its simplicity and relative cheapness ; because packages exceeding 100 pounds weight are not easily fed on to the moving swing-trays and removed from them by hand. So, for dealing with heavy packages, it becomes necessary to arrange automatic pick-up and discharge gear ; and frequently this is done even for fairly light packages, as a matter of convenience rather than of necessity.

In this type of elevator and lowerer (shown in Fig. 24) each pivoted carrier is composed of a centre bar with transverse arms, suspended from the twin chains by two hangers or slings, which are usually malleable-iron castings. At each floor are provided loading and discharging tables or grids, arranged to intermesh with the carriers. Thus an article (whether box, bale, bag or barrel) placed on any loading grid is gently picked up without shock by an ascending finger-tray, taken up over the top shaft and lowered down to the delivery point. Here it meets the inclined discharging arms or fingers, which intercept and remove the load, while permitting the carrier to pass.

Both the loading and the discharge grids are *hinged*, to allow of quickly throwing them out of gear when not in use at any floor, thus enabling the load to pass to the next lower floor; but the bottom grids are usually *fixed*. In this way a series of packages can be delivered automatically in a regular stream at any predetermined floor. By suitably shaping the finger-trays or cradles, the same elevator can be adapted for handling both boxes and barrels simultaneously.

In the case of Fig. 24 the drive is by an electric motor through an enclosed worm-reduction gear, spur wheel and pinion, and chain drive to the top shaft. Push-button control is fitted. The driving gear is compactly arranged just below the ceiling of the sixth floor; while interlocking sets of hinged feeding and discharging grids are fitted on each floor of the building, as also a push-button.

The photograph (Plate VI) depicts how cases of tea enter a London warehouse from a finger-tray elevator outside the building; while Plate IV represents the fixed loading grid and a fingered carrier of an elevator designed to lift bales of wool weighing 8 cwt. and measuring 5 feet by 3 feet by 3 feet. Each carrier here consists of five bent steel flats riveted to a steel channel, which in turn is bolted to two malleable iron end-slings hanging from the special long joint pins of two No. 500 Gray type chains of 6-inch pitch. Obviously the intermeshing loading grid needs to be of substantial construction to receive the heavy bales. To steady the slings the lower ends run in vertical guides, small guide wheels being often fitted.

Table III summarises the leading technical data of four actual finger-tray elevators and lowerers. Of these C

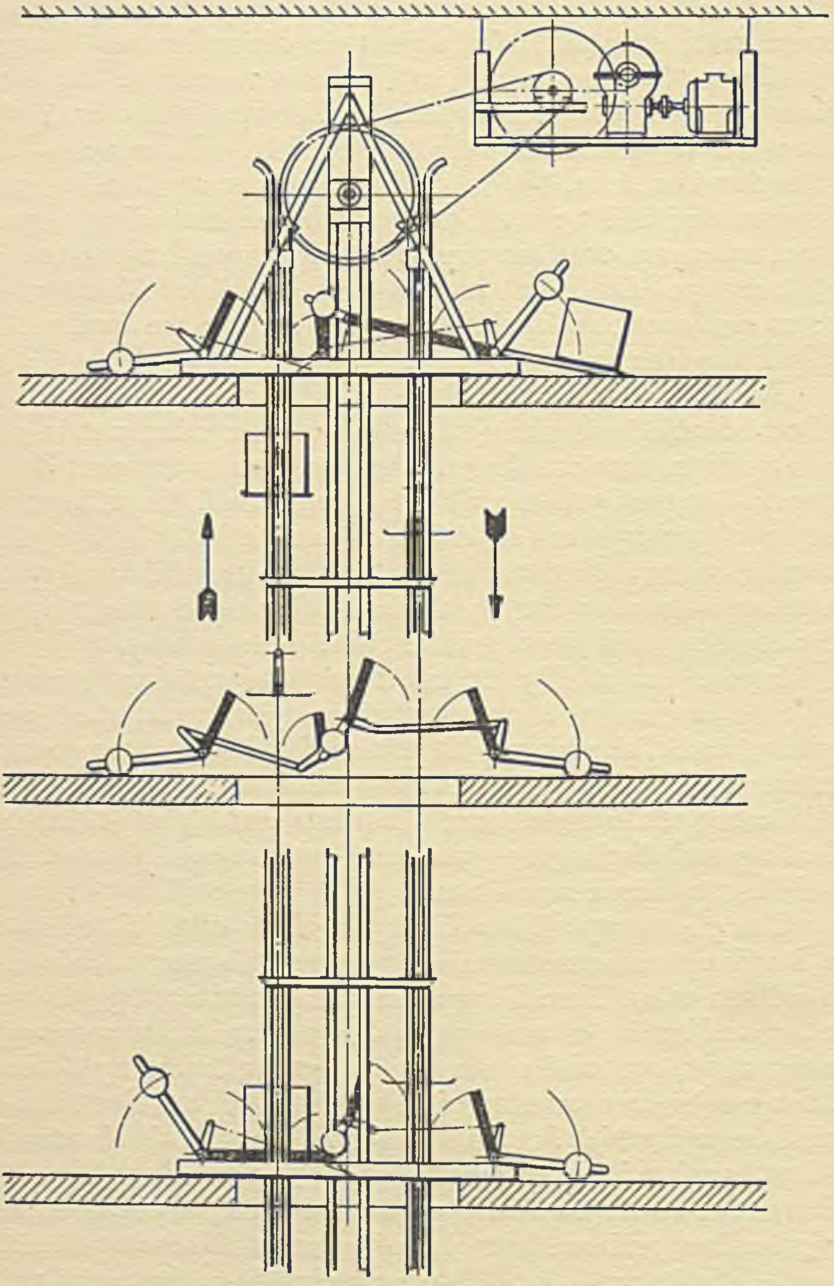
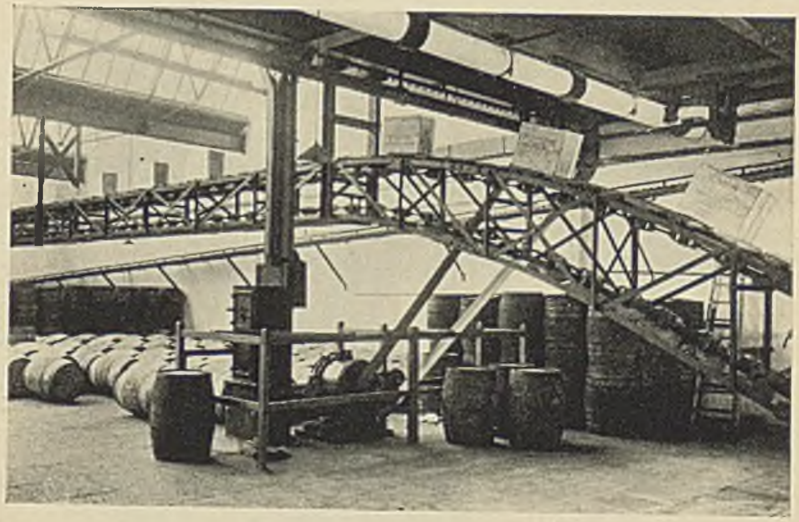


FIG. 24.—Automatic Finger-tray Elevator.

HORIZONTAL TURN IN SOAP-BOX CONVEYOR.



VERTICAL BEND IN ABOVE SOAP-BOX CONVEYOR.

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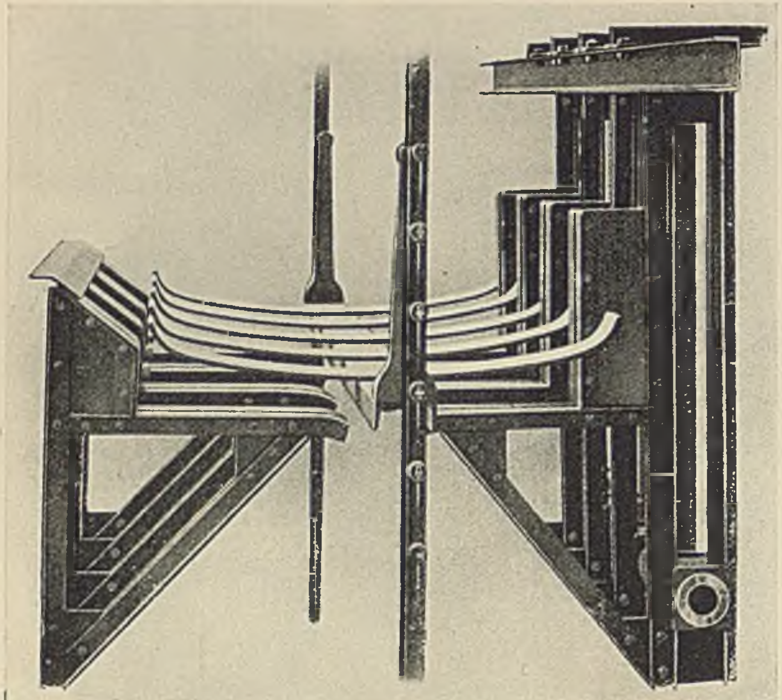
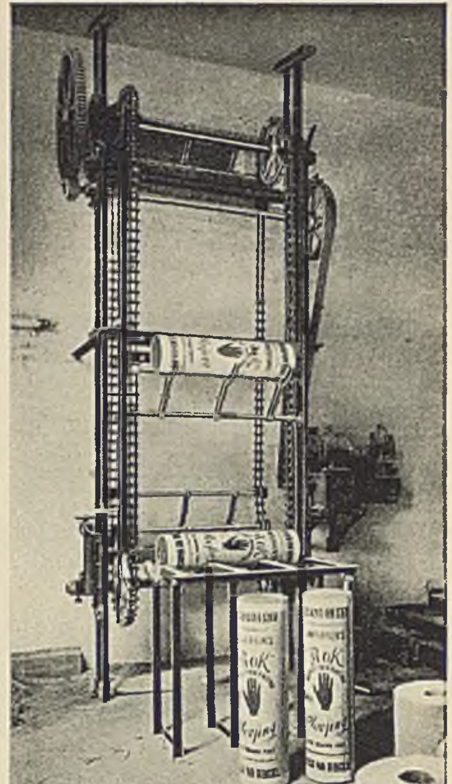


LOADING GRID AND FINGERED CARRIER FOR 8-CWT. BALES OF WOOL.



ARM ELEVATOR FOR ROLLS OF FELT.

handles trays of small mechanical details and has the longest centres (75 feet); while D handles the largest individual loads of 700 pounds. Electromagnetic or solenoid brakes should be fitted to heavy elevators, though often omitted.

TABLE III—FINGER-TRAY ELEVATORS

	A	B	C	D
Ref. Index . .	Robinson	Lyle	Lucas	Birch
Goods lifted . .	Cloth	Sugar bags	Details	Cases
Pitch of carriers .	11 ft.	8·75 ft.	7·5 ft.	12 ft.
Chain speed per min.	51 ft.	60 ft.	15 ft.	40 ft.
Loads per hour .	278	410	120	200
Shaft centres . .	38 ft.	56 ft.	75 ft.	73 ft.
Ley's chain used .	No. 79	No. 500	No. 500	No. 555
Diam. of top wheel .	39 in.	60 in.	46 in.	85 in.
Diam. of top shaft .	2·5 in.	3·5 in.	4 in.	5 in.
Power of motor .	3 H.P.	6 H.P.	4 H.P.	12 H.P.

6. **Finger-tray Elevator for Cloth.**—In the discussion following the reading of my Manchester paper of 1913, one member present (Mr Joseph Butterworth) said that he would like the author to tell them why conveyors were not more largely used in Manchester warehouses. If they took an ordinary warehouse in Portland Street, the packages were of similar size and character. He believed there were about 40 tons a day of yarn or cloth sent out from one large warehouse, and the hoists were either hydraulic or electric, costing £250 to £300. They had to have an attendant, which was not necessary with a conveyor.

In the reply to the discussion it was stated that probably the reason why continuous vertical elevators or conveyors were not more used in Manchester warehouses was that most firms had already installed cage hoists before they knew anything about conveyors; and now, having already got hoists which answered the purpose, though not with maximum economy, they were loth to make an alteration that would cost money. However that might be, a cloth elevator of the continuous finger-tray type was then in course of construction, at a cost below £200, including an electric motor.

This economical and successful cloth elevator was erected in June 1913. It connects the ground floor of the warehouse to the basement and two upper floors. The malleable iron carrying arms and discharge fingers, normally in contact with the load, are here covered with wood guards fitting like gloves. Some particulars of the machine appear in Table III under column A. This elevator is depicted in the half-tone view (Plate V) facing page 64.

7. **Automatic Gravity Lowerers.**—A vertical swing-tray elevator can be used for lowering through several floors, as well as for elevating. When utilised for lowering only, a belt drive is convenient for regulating the rate of lowering and acting as a brake, although the consumption of power is practically *nil.*

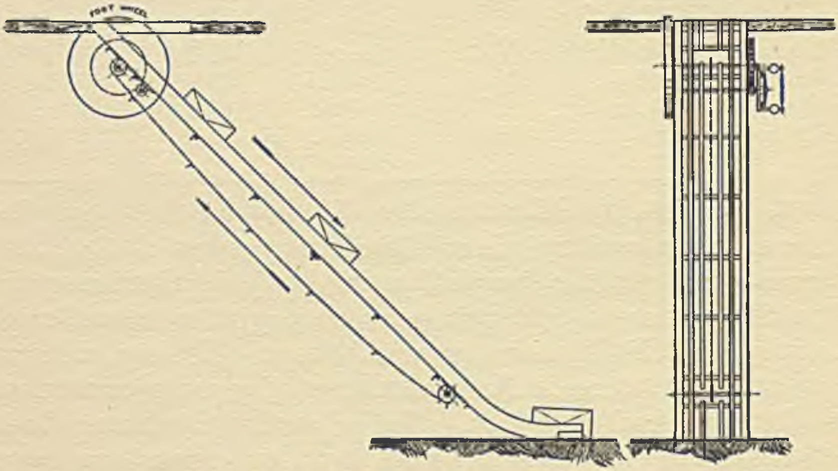


Fig. 25.—Controlled Gravity Chute.

Where no motor or other source of power is available, however, an automatic brake controlled by a centrifugal governor may be fitted instead, and the lowering done entirely by gravity; the governor preventing excessive acceleration. The main objection is that the swing-trays will seldom come to rest in the most suitable position for loading them, a fault from which positively driven lowerers are free.

Fig. 25 shows a modified form of inclined chute, which automatically controls the rate of descent of the load by means of an endless chain fitted with angle carriers and a centrifugal governor geared to the top shaft. This useful contrivance has been successfully applied to the lowering of soap boxes and full bottles of beer in crates. Photographs of these applications are given in the writer's original paper of 1913.

CHAPTER V

CONVEYORS FOR COMBINED VERTICAL, HORIZONTAL AND INCLINED MOVEMENT (CLASS C)

1. **Simple Swing-tray Conveyors.**—By a slight modification to a vertical swing-tray elevator, the same type of machine can be readily adapted for conveying goods in a horizontal direction, after having been raised vertically; the chains being now provided with rollers or supporting wheels running on angle-iron tracks, as diagrammed in Fig. 26. An enormous extension in the scope and utility of the machine is thus secured; a fact which further emphasises its marked superiority over the cage hoist for the transport of great quantities of similar packages.

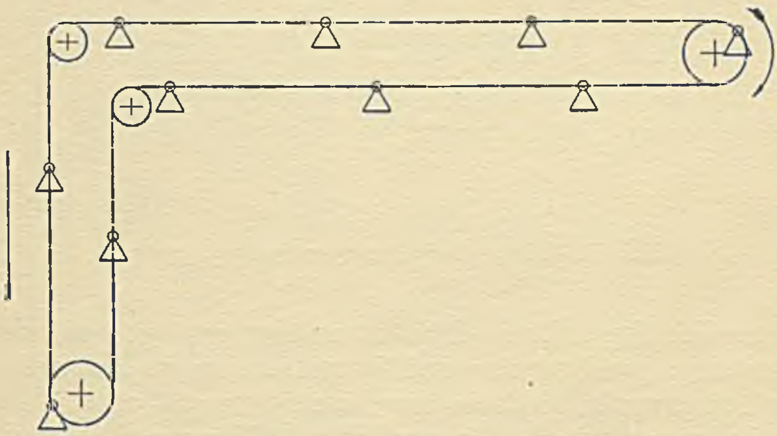


FIG. 26.—Diagram of Swing-tray Conveyor.

It is evident that the path of the chains is not confined to the vertical and horizontal directions. It may be inclined at any angle or even curved; a variety of combinations being thus available. The nature of the path is determined by the nature of the site, by the relative positions of the machines to be served and by the impediments to be cleared. Thus every conveyor has to be designed specially to suit the local conditions and requirements. Standardisation and quantity production are clearly impossible as regards conveyors, no two being precisely alike in form and dimensions. Happily, however, certain details, such as chains, have been fully standardised by several reputable firms and are conveniently available in various materials, both ferrous and non-ferrous.

In the writer's 1913 paper on "Package Conveyors for Factories" drawings and details were given of a large swing-tray conveyor for carrying a stream of skips containing cops of cotton yarn in a Lancashire spinning mill to and from

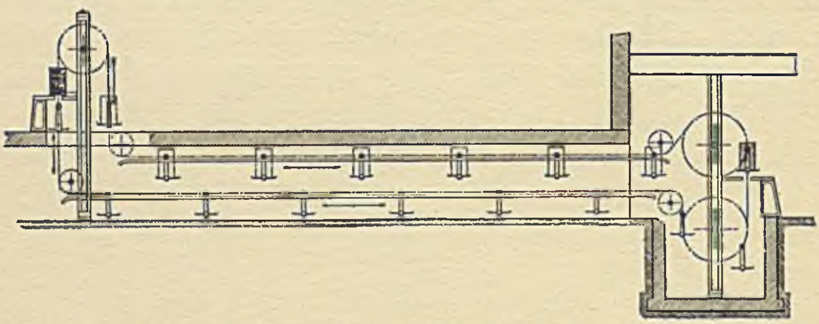


FIG. 27.—Finger-tray Conveyor for Newspapers.

the conditioning cellar.[1] This interesting conveyor has given remarkably good service and is still doing its daily duty. The two strands of chain have a total length of 910 feet, yet the power absorbed is negligible. The speed is 40 feet per minute, and the carrying capacity 150 skips of 90 pounds each per hour, with the swing-trays spaced 16 feet apart. See Table IV, item A, page 38.

2. **Finger-tray Conveyors.** — By providing fingered carriers and suitable grids at the feeding and discharge points, it is easy to arrange for the automatic picking up and delivery of packages, instead of their removal by hand. A neat example of a finger-tray conveyor is given in Fig. 27. This takes bundles of loose newspapers from the machine or press room to the publishing or dispatch room of a London daily paper.

[1] See also Zimmer's "Mechanical Handling," vol. i, p. 140.

On account of the available floor space in the press room being so limited, it was necessary in this case to run the conveyor in a tunnel below the floor, as indicated in the vertical cross-section (Fig. 28). The carriers are spaced at 6 feet and the capacity of the machine is 12 bundles per minute or 720 per hour, equal to about 173,000 copies of the newspaper.

In the Cutler-Hammer newspaper conveyor the papers are fed in a continuous stream on to several strands of

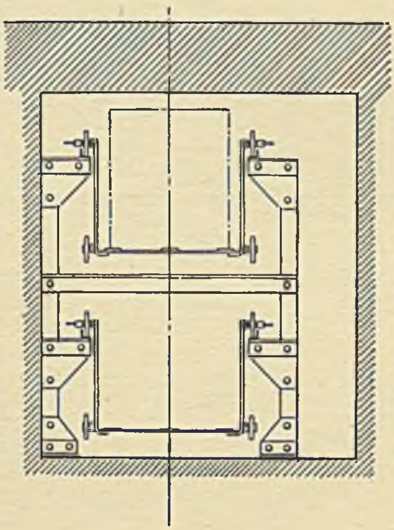


FIG. 28.—Cross-section of Finger-tray Conveyor.

coiled spring steel wires, between which the papers are gripped for the vertical movement (see Zimmer, vol. ii, Fig. 1248).

A successful example of a finger-tray conveyor erected in Manchester handles both full barrels of fat and sacks of flour between a store and the main four-story building separated by the factory yard. Goods can be conveyed in both directions and delivered automatically at any floor by a system of hinged feed and discharge grids. An automatic friction governor is provided to prevent overrunning. For further particulars see item C in Table IV, which also gives useful data for three other conveyors.

Table IV—Swing-tray and Finger-tray Conveyors

	A	B	C	D
Ref. Index	Eckers	Watney	Hugon	Marston
Goods lifted	Skips	Beer boxes	Bags, etc.	Casks
Pitch of carriers	16 ft.	7 ft.	10·5 ft.	8 ft.
Speed per minute	40 ft.	45 ft.	45 ft.	40 ft.
Loads per hour	150	380	260	300
Vertical centres	58 ft.	22 ft.	60 ft.	15 ft.
Horizontal centres	146 ft.	107 ft.	80 ft.	100 ft.
Length of circuit	455 ft.	265 ft.	346 ft.	283 ft.
Ley's chain used	No. 5079	No. 5079	No. 555	No. 500
Diam. of main wheel	35 in.	35 in.	58 in.	38 in.
Diam. of main shaft	3¼ in.	3 in.	4 in.	3 in.
Power of motor	3 H.P.	5 H.P.	6 H.P.	8 H.P.

CHAPTER VI

MOVABLE SACK PILERS

ALL the conveyors so far considered have been fixed machines. During the last thirty years there has been a marked increase of interest in movable or portable elevators of different kinds and their application. Some of these machines are self-propelled, others have to be hauled about. Some with large wheels are stable on rough ground, whereas others with small wheels and swivelling castors are suitable only for travelling over smooth warehouse floors. Some movable elevators are rather complex-looking machines, and others are of great simplicity. They also vary considerably in size, weight and cost.

The drawing (Fig. 29) shows a machine used in a beet-sugar factory for piling 3-cwt. sacks of sugar. It is self-propelled at the rate of 30 feet per minute. The track is 9 feet 9 inches by 5 feet gauge; the travelling wheels being 21 inches diameter and the castors or steering rollers only 8 inches diameter. The source of power is a 3-phase motor of 4 H.P., running at 950 revolutions per minute. A push-button control gear is fitted, which automatically limits the angular movement of the hinged boom to 40 degrees.

The lower or fixed feeding boom is 7 feet centres and the main boom 29 feet centres; the maximum lift being 24 feet from the ground to the top shaft. The elevator running gear comprises a series of $1\frac{1}{4}$-inch square carrier bars bolted to **K**-type attachments of Ley's No. 170 pintle chain of $1\frac{3}{4}$-inch pitch; the endless twin chains engaging with sprocket wheels of small diameter. The chain speed is 80 feet per minute, giving a capacity of 12 sacks a minute when spaced at intervals of 6 feet.

As seen in the drawing, the motor drives by a belt on to a transverse countershaft, from which all the motions are actuated through a system of mitre wheels, double-acting cone-clutches and worm-gears.

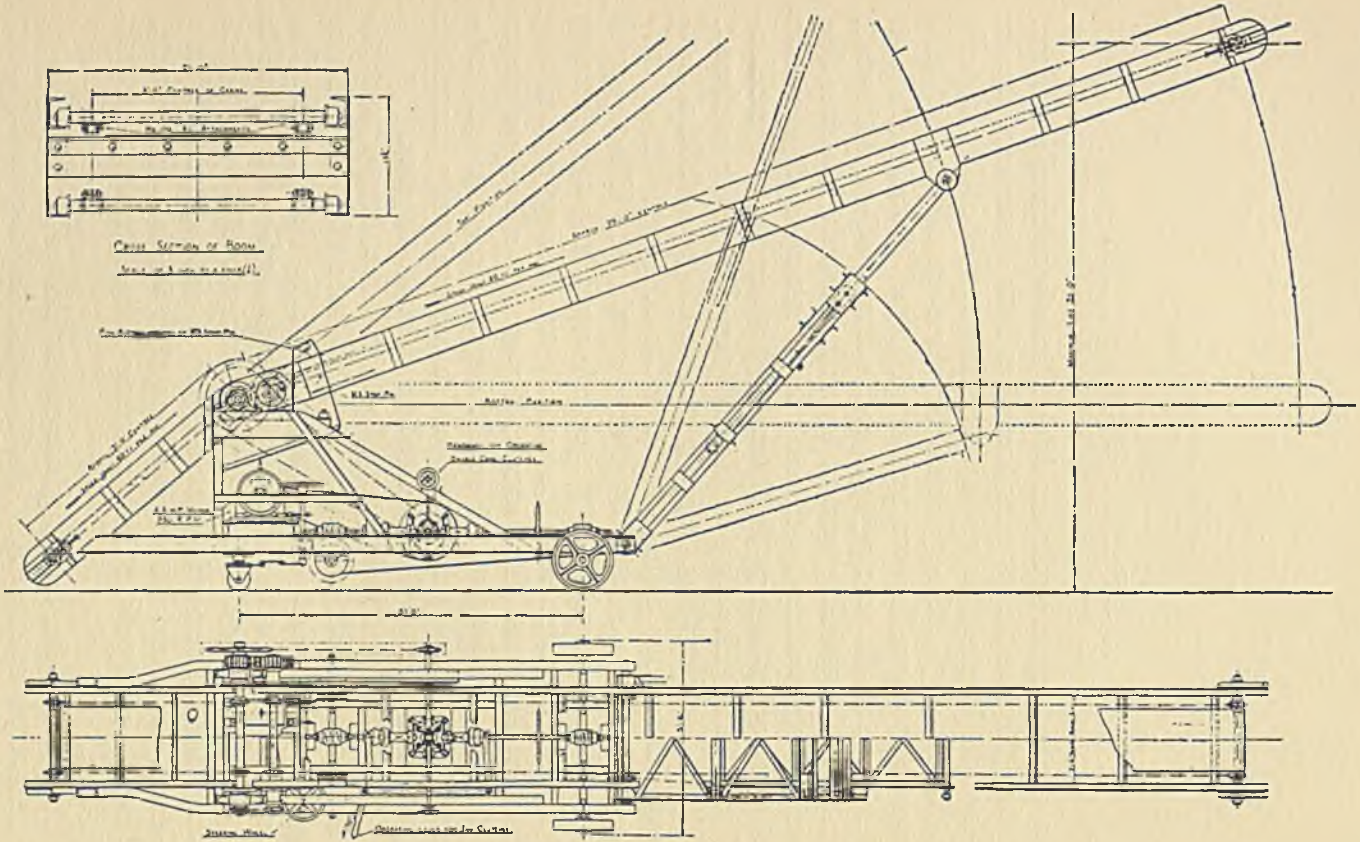


FIG. 29.—Drawing of Heavy Sack Piler.

The telescopic strut, controlling the angular position of the main boom, is hinged to the underframe and fitted with a system of grooved pulleys, arranged to give a purchase of four to one. Thus the strut can be adjusted in length by coiling up two wire ropes, $\frac{1}{2}$-inch diameter, on a pair of drums; which are driven by a worm-gear through a longitudinal countershaft fitted with jaw-clutches for ready disconnection.

The photographic view (Plate VII) depicts a lighter type of bag piler for lifting 200-pound bags up to 15 feet high, at a speed of 50 feet per minute. The Ley's chain used is No. 151 with K1 attachments for the crossbars.

For other examples of stacking machines and portable elevators see Zimmer's "Mechanical Handling," vol. ii, p. 648.

CHAPTER VII

OVERHEAD MONORAIL CHAIN CONVEYORS (CLASS E)

Of recent years great progress has been made in the development and application of overhead monorail conveyors for moving isolated articles and goods in containers. Their flexibility is indeed remarkable, especially when fitted with a biflex chain. Some of these single-chain conveyors are very long, in fact, over a mile in length in certain motor-car factories; having multiple drives through self-adjusting fluid couplings, in order to distribute the load equally between five or six motors.

As monorail conveyors can often be suspended from existing roof principals, they need but little special supporting framing, and their first cost is extremely low, often below £1 per foot-run. Another advantage is that they occupy no valuable floor space. These conveyors are eminently adaptable to a complex layout in factories engaged on light repetition work, such as bicycles. They have also found extensive application in grey iron foundries producing large numbers of similar light castings.

Preselective devices can be added, enabling packages to be delivered automatically at any one of several alternative delivery points. But such devices considerably increase the cost and complication. At the Beeston works of Boots Pure Drug Co. Ltd., there is a fine example of a monorail conveyor with tipping trays feeding goods to a series of sixteen packing tables prior to dispatch to the different retail shops.[1]

1. Referring to Fig. 30, a light overhead chain conveyor

[1] See Koshkin's "Modern Materials Handling," p. 296, for an account of preselective distribution controlled electrically. The photo-electric relay provides a means of selective handling of different articles on a system of conveyors, because of its sensitiveness to an increase or decrease of light falling on the cell.

was installed at a mill in Blackburn to carry full bobbins of cotton yarn from the bobbin-winding machine past a series of knitting machines. The operative in charge of the winding machine loads the full bobbins on to suspended carriers, and the knitting machine girls take off these bobbins as wanted. The empty bobbins are returned to the winding machine on

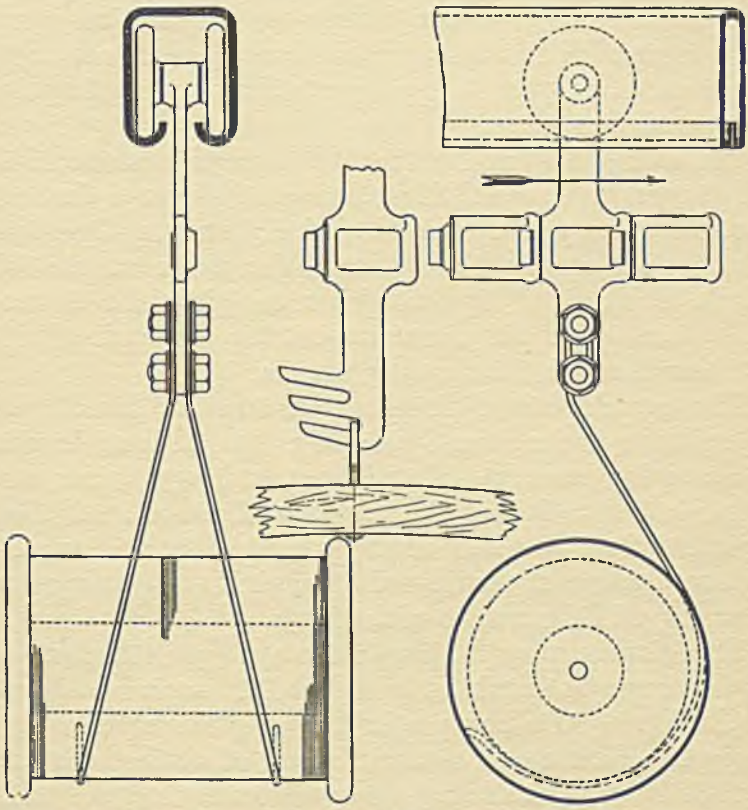


Fig. 30.—Carriers for Light Overhead Chain Conveyors.

the same carriers and are automatically knocked off into a box. Previously boys were employed to carry the full bobbins to the knitters and to bring back the empty bobbins. This meant that at times certain knitters would be kept waiting for a supply of yarn.

This simple conveyor has a circuit of 350 feet. It consists of a No. 33 light Ewart chain, with wire-hook carriers at 3-feet intervals, suspended 6 feet above floor-level. Above the chain, at 18-inch pitch, special attachments are fitted, each having two small wheels, which run in a pressed steel Coburn track stayed to the ceiling and to existing pillars.

The diameters of the driving and tension sprocket wheels are 24 and 18 inches respectively, while 12-inch corner wheels suffice. At a chain speed of 24 feet per minute the carrying capacity is 480 full bobbins per hour. This conveyor is driven from an existing lineshaft running at 240 revolutions per minute through a belt drive, a spur reduction gear and a bevel gear. The tension gear is of the automatic gravity type, a set of weights taking up any slack and so keeping the chain tension constant.

2. During the last few years a Lancashire firm of dyers and cleaners have installed in their works over a dozen light monorail conveyors for serving their various departments, including the spotters, the pricers, the steamers, the folders and the finishers. "Spotters" are the girls who detect any marks needing special treatment on the garments after they have been through the cleaning process.

The special carrier hook attachment for No. 33 chain is also shown in the same figure (Fig. 30). It is made suitable for conveying garments placed on coat-hangers, the carriers being pitched 8 inches apart. The Coburn steel track is suspended from the roof of the various departments served. The supports are of the tie-rod type, giving a light appearance in keeping with the nature of the loads.

The circuits vary in length from 40 to 460 feet. The longest conveyor needs only a $\frac{3}{4}$ H.P. motor to drive it; thus indicating the low power consumption of this type of conveyor. An average constant speed of 40 feet per minute was found to be suitable for the operators to load and unload; though the speed was as low as 10 feet per minute in the spotters and the stove conveyors.

Exceptionally the pricer's conveyor is hand-operated through a handwheel, a chain and bevel drives; the employee who prices each garment also operating the conveyor.

3. The radiators branch of Morris Motors Ltd., Oxford, is completely conveyorised, that is to say, all transport of raw materials and parts is done by means of overhead conveyors in a regular flow. The loads carried include rolls of steel strip weighing 1 cwt. each, also boxes of gills and tubes, and finished radiators weighing 30 pounds. The half-tone

(Plate VIII) shows a driving terminal of one conveyor carrying rolls of brass and steel strip up an incline from the stores on the ground floor, and also taking boxes of pressings and tubes down to the assembly department.

The track in some parts is horizontal and in other parts inclined, while there are numerous bends; thus necessitating the use of a biflex chain (Fig. 31). This particular biflex or universal chain (No. MU 4) is of 4-inch pitch, with alternate pins at right angles. In one conveyor at this factory the chain is 480 feet long, in another 950 feet, and in each of two assembly conveyors only 80 feet long. Each conveyor has its own motor, driving through compact reduction gear to give a chain speed of 15 feet per minute.

4. The Hercules Cycle Co. Ltd., Birmingham, have installed

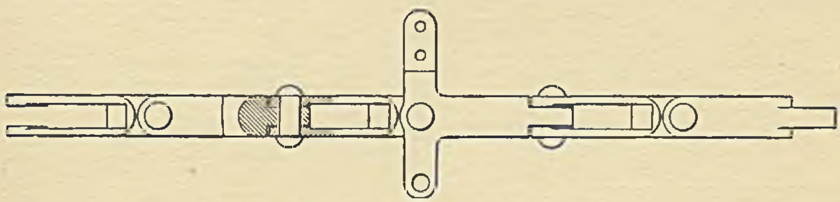


FIG. 31.—Biflex or Universal Chain.

a large number of conveyors in their extensive bicycle factory. The photographic view (Plate VIII) represents a small part of a special monorail conveyor of 954 feet circuit, carrying 450 handle-bars and 450 boxes of small parts per hour from the mopping shop to the brake assembly and gear stores. It has 24-inch chain wheels and Ley's No. 157 pintle chain, with K1 attachments $34\frac{1}{2}$ inches apart, running at 45 feet per minute.

The trolleys have twin rollers $3\frac{1}{4}$ inches diameter bored for $\frac{3}{8}$-inch pins, and the double carrier hooks are made of $\frac{3}{8}$-inch round bar. The trolleys run inside of a 4-inch by $1\frac{3}{4}$-inch steel joist track. On account of the length and the layout there is one gravity tension gear as well as two screw tension gears. This conveyor is driven, through bevel wheels and an H.R. or Hatcher reducing gear,[1] by means of a 3 H.P. motor. Its cost did not much exceed £1000.

5. Another example of a monorail conveyor (a much heavier

[1] See Chapter XIII.

job) may be referred to, as used by a canning company in Lincolnshire. Plate IX depicts a universal conveyor of 120 feet run or circuit, taking cans of peas in containers through a cooling tank 40 feet long at a speed of 2 feet per minute. The loads are heavy, amounting to half a ton, and

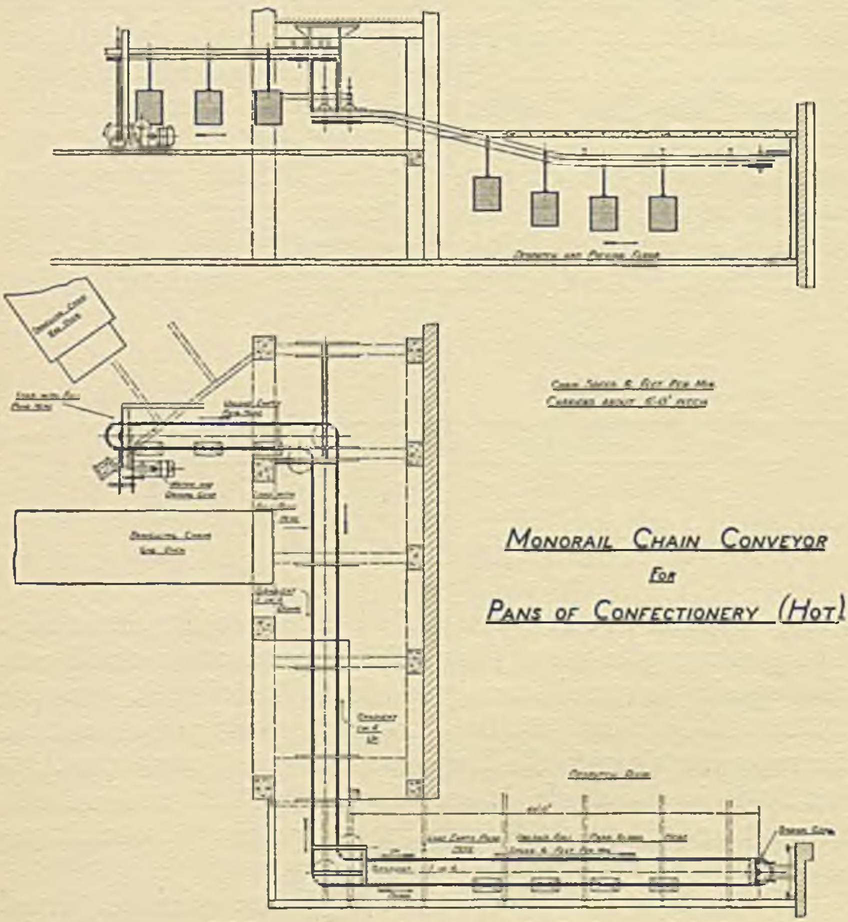


FIG. 32.

cannot be handled by hand. Actually the loads are put on the carriers with the aid of an air lift and removed by means of a special lifting truck.

This conveyor has 28-inch chain wheels, also No. 15 Vale biflex chain and K14 attachments at 32-inch pitch, secured to carriers having twin ball-bearing rollers, 5 inches diameter, running inside of a 7-inch by 3½-inch R.S.J. track. On account of the slow chain speed, the power actually needed to drive this fairly heavy conveyor is only half a horse-power.

6. A confectionery conveyor of an interesting character, erected at a large bakery in Glasgow, is clearly shown in Figs. 32 and 33. This machine takes full pans (each 12 pounds) of cakes and pies in a series of 14-decker cages from a pair of continuous gas-ovens down an incline of 1 in 4 to

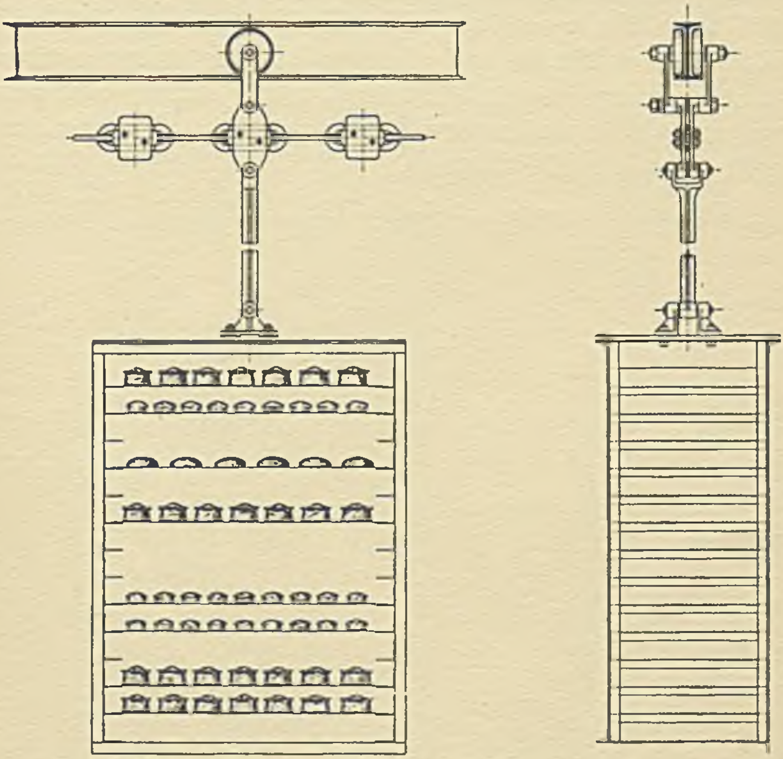


FIG. 33.—Trolley and Cage for Cakes and Pies.

the packing and dispatch floor, returning the empties to the upper floor. The circuit is about 230 feet.

A strong and simple form of biflex chain is used, viz., $\frac{5}{8}$-inch Dodge cable chain running at a speed of 6 feet per minute; the carriers being spaced 6 feet apart. Thus the carrying capacity is 60 loads per hour. The total weight of a loaded cage is 310 pounds. A variable-speed D.C. motor of 4 H.P. drives the conveyor through a worm-reducing gear, two sets of spur gears and a pair of bevel wheels. The main sprocket wheel is 30 inches diameter and the main shaft 4 inches diameter.

In another monorail conveyor using a similar chain the circuit of the chain is 606 feet and its speed 25 feet per minute. It was erected in a Lancashire artificial silk factory. The carriers are loaded with bobbins of silk in the spinning room, moved a distance of 110 feet horizontally and 15 feet vertically into the twisting room, where the carriers are unloaded from the conveyor. The carriers are reloaded on to the conveyor at the far end of the twisting room and returned to the spinning room. This and other examples[1] prove conclusively that the monorail conveyor is readily applicable to a large variety of industries.

[1] See also Zimmer's " Mechanical Handling," vol. ii, p. 871.

CHAPTER VIII

CONVEYOR CHAINS AND WHEELS

ALTHOUGH there are numerous designs of conveyor chains on the market, both standard and special, there are perhaps about a dozen types which are pre-eminently useful and successful, representing the survival of the fittest; and these will be considered in some detail. They are all well-tried chains, having been on the market for periods long enough to prove their worth, even up to half a century; moreover, they are readily obtainable from several sources.

Some of the types of chain to be considered are also successfully utilised as *driving* chains; but as a rule chains for transmitting power are of shorter pitch than conveyor chains and run at much higher speeds. The running speed of the latter ranges from less than a foot a minute up to a maximum of about 200 feet per minute; whereas some drive chains may run at 2000 feet or more.

The most important detail of a chain-belt conveyor or elevator is undoubtedly the chain itself; the proper choice of a chain for a particular duty being of vital interest to the successful operation of the whole machine. The subject of conveyor chains is indeed a very big one in itself; especially when one considers the multiplicity of methods adopted for attaching chains to the various forms of load carrier; including under that title elevator buckets as well as conveyor slats, trays and scrapers.

The steel roller chain has been used very largely for gravity-bucket coal conveyors in power houses, and it finds increasing application elsewhere for some other duties. It has been made for exceptional duty up to 36-inch pitch; being convenient to apply when no regular stock or standard chain of another type is available.

Apart from the steel roller chain and the Dodge cable, the chains referred to above are generally made of malleable cast iron, preferably cast from a reverberatory or air furnace, and not from a cupola; because in the latter case the molten metal can absorb sulphur, silicon and other impurities from the coke in contact with the metal. Other materials sometimes utilised for making such chains are wrought iron drop forgings, steel stampings, mild steel and manganese steel castings, also gun-metal and phosphor-bronze castings. All these alternative materials are naturally more expensive than malleable iron, but are being increasingly used.

Malleable iron chains are not greatly affected by a moderate degree of heat; so that they can be used successfully in connexion with continuous drying oven and furnace work. The tensile strength of Ley's blackheart malleable iron is about 60,000 pounds per square inch and elongation about 15 per cent. on a length of 2 inches. Occasionally malleable iron links are galvanised to avoid corrosion. Sherardising is also adopted. A new alloy iron, known as "Ewmal," has recently become available for chain links. It contains a small percentage of copper and is specially resistant to corrosion in a dilute acid medium.

Most of the above chains are manufactured in a large range of sizes and strengths as standardised products by several reputable firms; and are consequently obtainable at short notice, with the same facility as standard bolts and standard steel sections, such as angles, channels and joists. Thus there need be no anxiety as to the possibility of obtaining renewals at short notice or from stock. This is of great practical advantage, both to the engineer and the user. The slow delivery of special chains is often a fatal objection to their adoption.

It is also important for quick delivery that a chain should be selected for which a good many sprocket-wheel patterns are available. Chains alone are useless without the wheels, and it takes a long time to make a new wheel pattern complete. Alternatively, one may use either machine-moulded wheels or machine-cut wheels.

1. **Ewart Pinless Chain.**—The first and best known of the above standard types is the Ewart detachable chain which was first brought out by William D. Ewart in 1873 and put on the market in America by the Link-Belt Co.,

of Chicago, and in Europe by Sir Francis Ley, Bart., of Derby.[1]

The Ewart chain has had an enormous sale, and is still appreciated on account of its great convenience and its relatively low cost. It is a singularly ingenious form of chain, chosen not for its appearance but for its general utility. In fact, it is the simplest of all conveyor chains, and has the great merit of being very quickly coupled up and detached, without the aid of joint pins. Thus it is easy either to

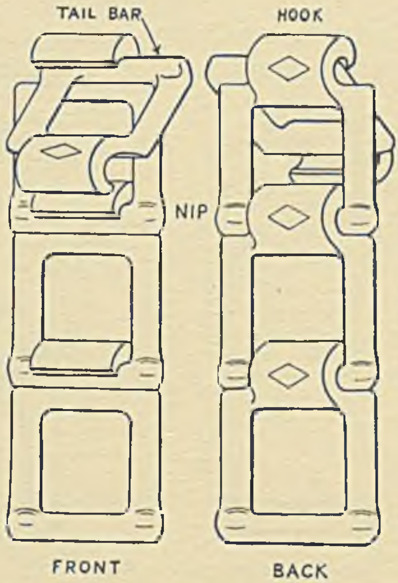


FIG. 34.—Method of Assembling Ewart Links.

shorten or to lengthen a Ewart chain at pleasure by removing or adding sufficient links to give the desired length. Yet it has its limitations and is not a chain to be lightly used for all occasions. There are other types that are more suitable for some purposes.

From Fig. 34 it will be seen that there is a flat or " nip "

[1] William Dana Ewart was the founder of the Ewart Manufacturing Co. and the first president of the Link-Belt Engineering Co. He died in 1908.

Sir Francis Ley, Bart., founded Ley's Malleable Castings Co. Ltd. and the Chainbelt Engineering Co. He died in 1916.

In the year 1923 I was privileged to visit the various plants of the Link-Belt Co.; now probably the largest makers of chains and conveyors in the world, having extensive factories in Chicago, Indianapolis and Philadelphia.

on one of the sidebars of each link, which permits the tailbar of one link to enter the hook of the next link in one position only. Yet the links when fitted together cannot fall apart while in the working position with any tension on the chain. Some Ewart chains are made "double-nip," *i.e.*, with a flattened place on both of the sidebars. In a double-strand elevator it is often convenient to use double-nip links, on account of the attachments being right and left handed; but as a general rule single-nip links are preferable.

In a plain chain, as used for driving, all the links are alike; but it is very convenient to use one coupling link

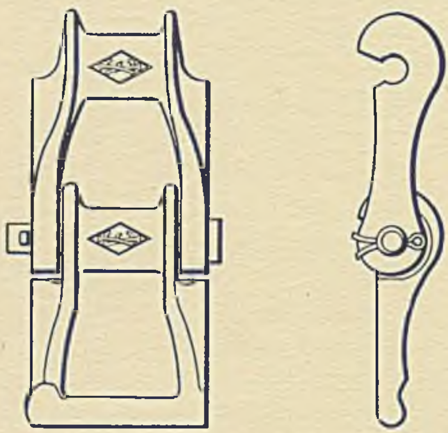


Fig. 35.—Ewart Coupling Link.

fitted with a pin, when the centres of the shafts are fixed. This coupling link (Fig. 35) avoids starting up with a very slack chain and is almost a necessity when no idler wheel is fitted to take up the slack.

Ewart chains will run in either clean or dirty situations, either with or without lubrication; but in the latter case the life of the chain is naturally shorter. In some situations lubrication is hardly feasible. The direction of motion of the chain giving the least sliding action in contact with the sprocket-wheel teeth, and therefore minimum wear, is indicated in Fig. 36; the tailbar leading and the pressure of the wheel teeth coming on the outside of the hook, and not between the sidebars.

Wear of the chain then takes place both on the inside of the tailbar, due to the working tension, and also on the outside of the hook, due to the action of the wheel teeth. *Conveyor* chains of the Ewart type should always be run with the back of the hook bearing against the teeth of the driving sprocket wheel. On the other hand, *driving* chains will run and wear equally well or better in the opposite direction. In a chain drive the load is the same on both the driver and the driven wheels ; whereas in the case of a conveyor or elevator the load is much greater on the driver.

It is usually necessary to grind sprocket wheels to the correct pitch, but in course of time the chain wears, thus increasing the pitch of the links. Eventually the pitch of the chain becomes so much greater than the pitch of the sprocket teeth that the chain will mount and jump over the teeth.

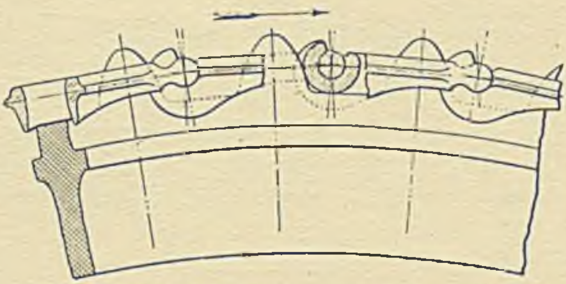


FIG. 36.—Correct Position of Chain on Wheel.

Chains which are worn to this extent must be replaced. Sprocket wheels also need renewing from time to time. As a rule it is not wise to put a new chain on old and worn wheels.

Wheels.—Sprocket wheels for light duty are usually made of cast iron and cast from metal patterns ; but on severe duty chilled metal wheels give far better service and are more economical in the end, in spite of the higher first cost. Cast-steel wheels are also used to a limited extent for the heavier chains. Wheels made in halves (split wheels), bolted together, are often preferred for elevator and conveyor main shafts, in order to facilitate overhauls and renewals.

Machine-cut chain wheels are more expensive than cast wheels, and have to be made of soft metal ; but small chain wheels in forged steel can be hardened after cutting, and make a very good job. Cut wheels are only feasible when required in good quantities, the cost being otherwise often prohibitive.

Chain Attachments.—The subject of attachments is a very big and important one in connexion with conveyor chains. It is easy to cast special bracketed attachment links of almost any required form on a Ewart chain ; thus facilitating the fixing on by either bolts or rivets of slats or buckets or other forms of carriers. A great variety of attachment links have been designed and standardised ; many such links being obtainable with the same facility as plain links from several manufacturers' stocks.

Some of the more common attachments are shown in Fig. 37. For convenience and conciseness of reference it has

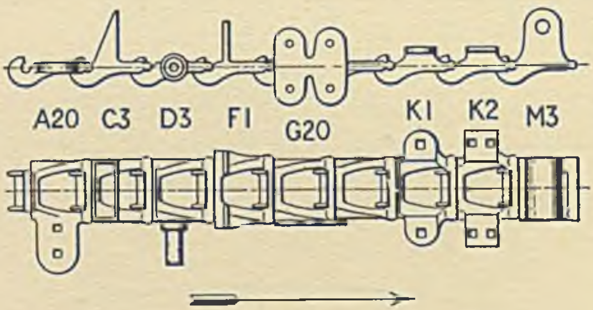


Fig. 37.—Ewart Chain and Attachments.

been found necessary to christen or give each kind of link a title of reference, consisting of a letter of the alphabet plus a figure, instead of a descriptive name, like " bucket link." These references are standardised throughout the conveyor industry and are well understood by all engineers making or using conveyors.

Taking a few examples, the K1 link is a bucket or a slat attachment having one bolt hole on each side of the centre-line, while K2 has two such holes. The G20 link is a side attachment, and is made both right and left hand. This link is suitable for carrying buckets in a double-strand elevator.

Again, the C3 link is a scraper attachment for conveyors of the push-plate or scraper type, and the F1 link may be similarly used. The bossed link M3 is designed for carrying the strut in an arm elevator (see Fig. 13). Lastly, the A20 link is made right and left handed, the projecting lug being suitable for bolting to the end of a slat in a double-strand slat conveyor. All double-strand conveyors and elevators must have their chains carefully " matched " before being put to work to prevent needless racking stresses being set up. This matter of matching multiple-strand conveyor chains is so important that it should never be neglected.

As a rule, an elevator chain will contain three or more plain links to one attachment link; but in a slat conveyor the attachments are usually continuous, there being no plain links at all. A Ewart chain made up entirely of special attachments might cost twice as much as plain chain; but, of course, attachments vary a good deal in cost according to their complexity. The extra cost is not merely a matter of so much extra weight of *material* as compared with the simpler plain chain; because attachment links are more difficult to mould and fit than plain links, and therefore more expensive to produce from the *labour* point of view.

Malleable iron chain of the Ewart type is commonly made in pitches varying from $\frac{3}{4}$ inch to 6 inches. The light patterns are much used in textile machinery, while the medium and heavy sizes are employed largely in conveyors and elevators handling grain and other light materials, as well as in sugar and coal elevators of small capacity. But for larger elevators pin chains are much better, as also for handling ashes, cement and other cutting materials.

There is a perplexing variety of sizes of Ewart chains to choose from, but Table V gives a helpful selection of twelve common chains for guidance. As a rule, renewals of these chains may be obtained from stock without delay; also a good range of wheel patterns is available, this being an important practical point.

In this short list the " cost ratio " figures indicate the relative costs of the chains; whilst the test load of a chain is given as about one-fifth of the breaking load as determined by a tensile chain-testing machine. For the *working* tension it is not wise to exceed half the *test* load. In order to ensure reasonable durability in working, the higher the rate of rotation of the sprocket wheels the lower should be the working tension. In conveyor work the chain should be supported either continuously or at short intervals by either skidders or rollers.

TABLE V—SHORT LIST OF EWART CONVEYOR CHAINS

Ref. No.	Cost Ratio.	Average Pitch.	Width.	Weight of 10 Ft.	Test Load.	Some Common Attachments.
		Inches	Inches	Pounds	Pounds	
33	1·00	1·38	1·1	4·2	170	A1, C3, K1, Carrier
42	1·29	1·38	1·4	7·2	400	A1, C3, D3, K1
48	1·14	2·03	1·6	6·6	400	A1, C3, G3, K1
57	1·50	2·32	1·9	11·6	600	A1, C3, D3, G20, K1
63	2·14	3	2·4	17·5	1,000	A1, C3, G3, K1
74	2·80	2·38	2·7	29	1,200	C3, G20, K1, F1
79	2·35	5·25	2·8	20	1,200	A8, D3, G20, K2, M3
88	3·00	2·66	3·4	37	1,500	C3, F1, G20, K1, M3
94	3·43	4·04	4·4	42	1,600	C3, G20, K1, K2
100	3·43	6·04	4·3	34	2,000	A8, C3, D1, K2
101	5·14	3·55	3·7	62	2,500	F2, G20, K1, K2
103	3·43	3·02	3·5	43	1,800	A20, C3, D3, G20, K1, M3

2. **The Vale Biflex Chain** is a simple modification of a Ewart chain, adapting it to articulate in two planes at right angles to one another. This ingenious form of chain belt has almost the flexibility of a rope. It enables a conveyor to be led round corners of buildings and over doorways; thus dodging many of those troublesome obstacles which often make the layout of a conveyor so difficult to arrange. Instead of removing obstructions to the straight-line path of a conveyor, it now becomes possible to take the track round or over such inconvenient obstacles.

The application of this chain [1] to a monorail conveyor is shown in Fig. 38, where biflex links at intervals are utilised in combination with plain Ewart links of 3-inch pitch to pull along a joist an endless stream of two-roller trolleys, from which the loads are suspended.

The Vale biflex chain is also applicable to conveyors of the slat type that will go up and down inclines and turn round corners. One such universal slat conveyor of 110 feet centres was made for handling tins of biscuits. This has 10-inch

[1] Refer to British Patent, No. 342,820, of February 1931.

shaped beech slats, bolted to the G1 attachments of No. 10 Vale biflex chain of $4\frac{1}{2}$-inch pitch, and supported by small flanged travelling rollers, running inside light steel channels

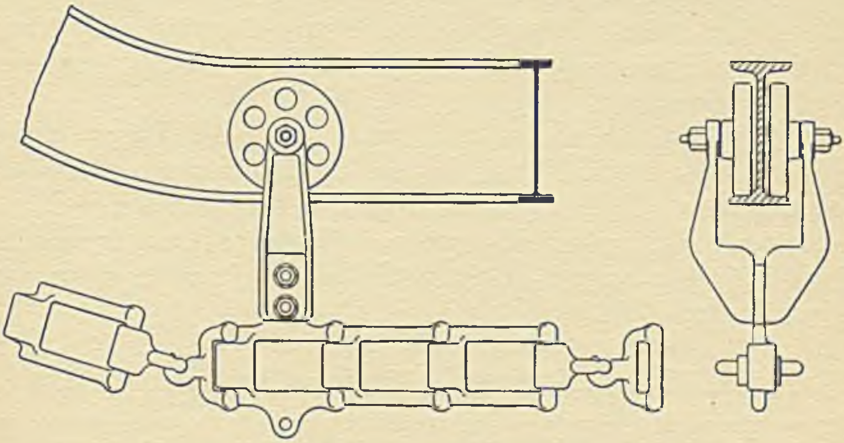


FIG. 38.—Trolley and Vale Biflex Chain.

and corner angles. The full tins of biscuits travel at a speed of 8 feet per minute, and are delivered down a short 14-inch roller runway on to a labelling table.

3. **The Pintle Chain.**—This neat and simple type of pin chain, non-detachable, is shown in Fig. 39. It is also known

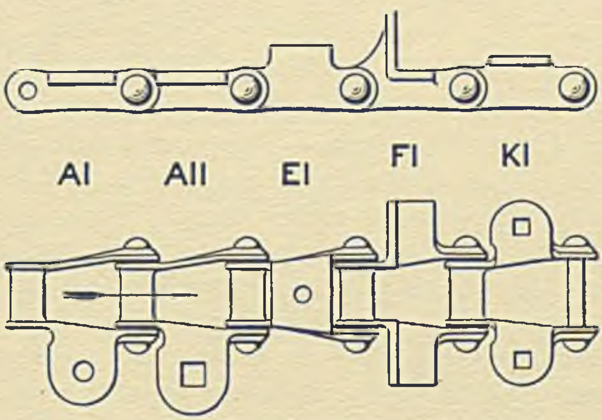


FIG. 39.—Pintle Chain and Attachments.

as Ley's riveted chain. The links are made of malleable iron and the cup-headed pins of bright steel, the ends being riveted over by a special machine. At intervals of 10 feet coupling pins are usually fitted. Alternatively the links may be fitted throughout with bright steel pins and cotter pins, so as to be easily detachable anywhere.

Pintle chains are both strong and relatively light. The joints, being closed, are almost dustproof, resulting in longer life of the chain. Though not made in heavy sizes, this form chain is of increasing application, both for transmitting power and for conveying.

Several pintle chains will work freely on Ewart chain *wheels* of like pitch. Thus the No. 133 pintle chain will work on the same wheels as the No. 33 Ewart chain, and it is far stronger. Naturally, it also costs much more. Certain helpful technical data regarding six useful sizes of pintle chain are given in Table VI.

TABLE VI—SHORT LIST OF PINTLE CONVEYOR CHAINS

Ref. No.	Cost Ratio.	Average Pitch.	Width.	Weight of 10 Ft.	Test Load.	Some Common Attachments.
		Inches	Inches	Pounds	Pounds	
133	1	1·38	1·5	13	800	A3, C3, K1, K8
155	1·17	1·61	1·8	16	1,300	A1, K1, M1, DK
170	1·5	1·75	2·2	28	2,000	A10, C3, D3, K1
158	1·17	2·04	2	17	1,400	A1, E1, F1, G20, K1
150	1·33	2·16	2·3	23	1,800	G20, K5, M3, M5
157	1·5	2·3	2·6	25	1,800	A3, C3, K1, K40, M3

4. **The Gray Pin Chain.**—This useful type is shown in Fig. 40. The body of the link is made of malleable iron, and the connecting pin of 0·4 carbon steel. The pins are fitted tightly into the sidebars, but not riveted over, and are readily renewable. The bearing area of metal in contact with the pin is made specially large to increase the durability.

Chains of the Gray type are not made in very small sizes, the shortest pitch being $2\frac{1}{4}$ inches and the longest 12 inches. They are intended to work on wheels made for Ewart chains of corresponding numbers, suitably strengthened. Thus No. 567 Gray chain will work on wheels made for No. 67 Ewart chain ; whilst No. 503 Gray chain of 3-inch pitch will work on sprocket wheels made for No. 103 Ewart chain ; though a little adjustment is usually necessary. Thus it is easy to replace an existing Ewart chain with a stronger type; a great practical convenience.

Gray chains are much stronger than Ewart chains, and the pin is more protected against corrosion and grit than the tailbar of the Ewart chain. Although more expensive than the

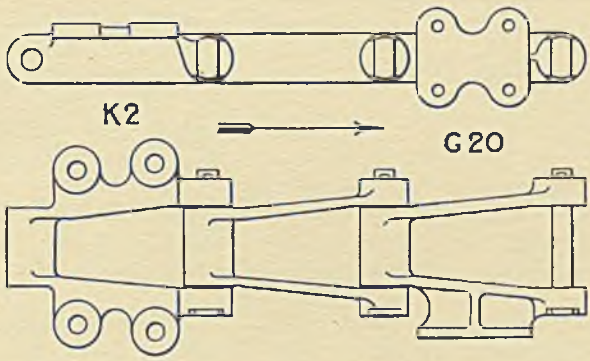


FIG. 40.—Gray Pin Chain and Attachments.

latter, the Gray chain is still economical in first cost; and it has a wide application in package conveyors, also for elevators and conveyors handling coal and sugar.

Fig. 41 shows how a malleable iron elevator bucket is secured to two strands of No. 330 Gray chain of 6-inch pitch, by means of swivel attachments and bolts. This mode of

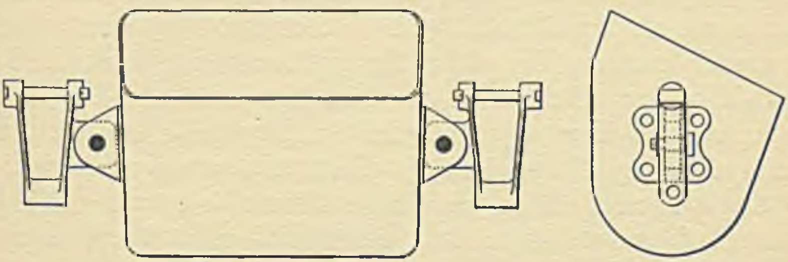


FIG. 41.—Swivel Attachment of Chain to Bucket.

carrying a bucket gives the necessary flexibility between the two strands of chain and avoids all racking stresses, even when the two chains are not properly matched. In the past it was customary to use G20 type attachment instead of AS2 type for the duty in question.

Table VII gives much technical information regarding nine common sizes of Gray chains, including a wide range of link attachments. See also Plate X, facing page 97.

TABLE VII—SHORT LIST OF GRAY CONVEYOR CHAINS

Ref. No.	Cost Ratio.	Pitch.	Width.	Weight of 10 Ft.	Test Load.	Some Common Attachments.
		Inches	Inches	Pounds	Pounds	
567	1	2·32	3·2	35	2500	F1, G20, K1, K2
578	1	2·63	3·3	40	3000	A1, F1, G2, G20, K1, K2, D30
5079	0·8	5·23	3·3	32	3000	A20, AD20, C3, D33, D50, D20, K2
503	1·3	3·02	4·4	62	4000	F1, G20, K1, K2, M3
504	1·7	4·06	5·7	85	5500	C3, K1, K2
444	1·8	4	4·3	91	5500	G25, M3
555	1·5	5·32	4·3	64	5500	D30, K1, M3
500	1·1	6·04	5·6	60	5500	AS20, C3, K2, M3
330	1·7	6·3	5·6	100	8000	AS20, G20, K2

5. **Sugar-carrier Pin Chains.**—A modified form of Gray chain with continuous E-type attachments is much used for the short inclined intermediate carriers connecting a series of cane-crushers in cane-sugar factories abroad. These carriers have multiple strands of chain riveted to overlapping corrugated and galvanised steel slats, as indicated in Fig. 42. Such chains are always driven by double or twin sprocket wheels, as seen in section (Fig. 43); the teeth engaging with the long outside bosses of the chains. The bits of cane have then a better chance of getting away freely along with the juice, and much clogging of the chain by pieces of fibre is prevented.

Sugar-carrier chains are made either of a special malleable iron or of cast stainless steel, fitted with stainless steel pins; but the latter is a very expensive material. The wear on the bosses is partly due to abrasion and partly to corrosion by vegetable acids present in sugar juice. "Ewmal" is one variety of corrosion-resisting malleable iron, which also possesses good physical properties, viz., a surface hardness of 159 Brinell, an ultimate tensile stress of 27 tons per square inch, a yield stress of 17·5 tons per square inch, and an elongation of 11·5 per cent.

Only two sizes of sugar-carrier chain need be mentioned here. The strongest size made is No. 901 E43 of 3·15-inch

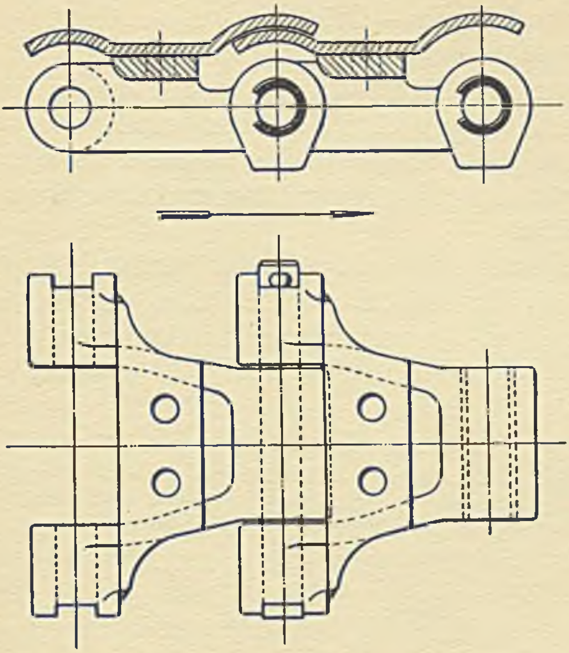


FIG. 42.—Sugar Carrier Chain on Corrugated Slats.

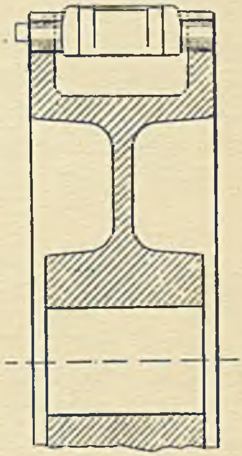


FIG. 43.—Carrier Chain on Twin Wheels.

pitch, having a test load of 6000 pounds. This chain (Fig. 42 above) is always made with bushed pin-holes, and has T-headed steel pins $\frac{5}{8}$-inch diameter. The most common size used, however, is No. 5174 E4 of 2·36-inch pitch, having a test load of 5000 pounds. The latter chain (Fig. 44) is regularly made either plain or with bushed pin-holes.

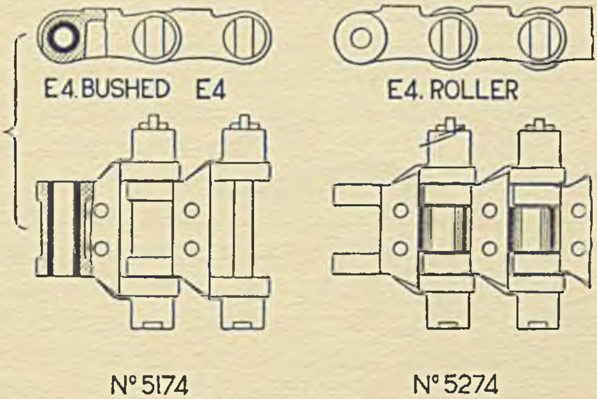


FIG. 44.—Ley's Bushed and Roller Carrier Chains.

6. **The Ley Bushed Chain.**—Of all the chains for bucket elevators that were ever designed, this type (Fig. 45) has probably been the most successful. It is a considerable improvement on the Gray pin chain, more especially for an elevator handling hard gritty materials like sand and cement; though it is used to an enormous extent for coal elevators in gasworks and elsewhere.

The Ley bushed chain was designed and patented many years ago by the late Sir Francis Ley, Bart., a pioneer in conveying machinery. Its special feature is the renewable hardened steel bush, held firmly at the ends and exposed in

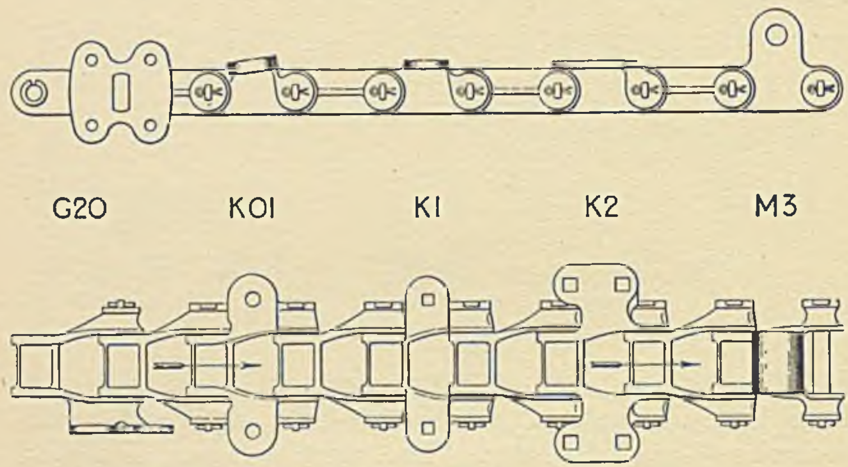


FIG. 45.—Ley Bushed Chain and Attachments.

the middle part, but prevented from rotating. This bush suffers wear internally, due to contact with the hardened steel pin under pressure and angular motion. But it is also subject to external wear due to the abrasion of the driving sprocket-wheel teeth, as the chain moves round the wheel (see Fig. 46). The external wear on the bush is decidedly the greater. The pins are of steel, casehardened.

These Ley chain *bushes* can be replaced by new ones when badly worn; and if the renewals are taken in hand in good time, this feature adds greatly to the life of the chain. When new pins and bushes are fitted to an old chain, the original pitch is restored and the chain takes on a new lease of life. But this reconditioning of the chain must not be delayed too long; otherwise the entire chain will be ruined

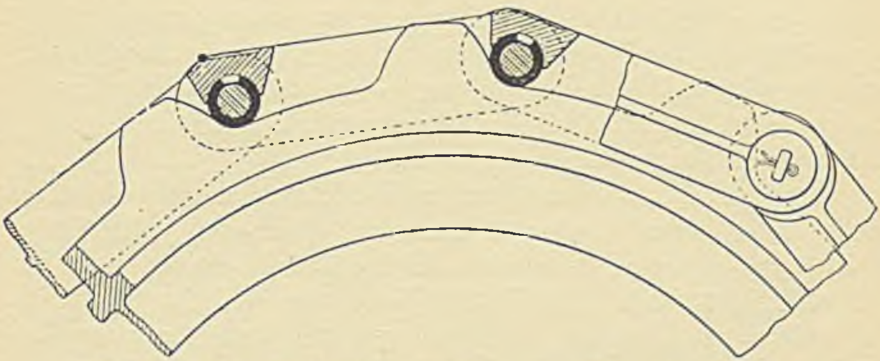


FIG. 46.—Ley Bushed Chain on Segment of Sprocket Wheel.

and both new chain and new wheels will be required. For specially severe duty both the pins and the bushes are often made of manganese steel, on account of the abrasion-resisting properties of this material. A chain is, in fact, obtainable in which the whole link is made of cast manganese steel, bushes being omitted. But this steel is apt to break without warning.

A selection of nine important Ley bushed chains has been made, whose characteristics are arranged in Table VIII.

Fig. 45 depicts several attachments. See also Plate X.

TABLE VIII—SHORT LIST OF LEY BUSHED CHAINS

Ref. No.	Cost Ratio.	Pitch.	Weight of 10 Ft.	Test Load.	Some Common Attachments.
		Inches	Pounds	Pounds	
603	1	3	74	4,000	AS20, G20, K1, K2
824	0·81	4	50	3,500	G20, K2
604	1·25	4·03	100	5,500	C3, K2, G20
600	1·125	6·04	104	6,000	C3, G20, K2, Claw
6140	2·06	6	180	8,500	C3, K2, Claw
7140	3·12	6·06	310	14,000	AS20, K22, Claw
612	1·125	12·04	98[1]	6,000	K2, K2D
1200	1·57	12·02	145[1]	8,500	K2, K2D
1207	2·25	12·04	210[1]	14,000	K2, K2D

[1] Including K2 attachment.

It will be seen that the lightest pattern of Ley bushed chain is of 4-inch pitch, whilst the heaviest pattern usually made is of 12-inch pitch. The most common pattern is the No. 600 chain of 6-inch pitch, which has had a long vogue for carrying buckets from 12 to 15 inches long. For larger buckets the No. 6140 K2 is often adopted, as shown in Fig. 47, four $\frac{3}{4}$-inch fixing bolts being used.

The actual manufacture of malleable iron conveyor chains involves a large number of technical processes, collectively occupying a considerable time. Indeed, chains made specially to order require a period of at least two months for their complete manufacture, even though the quantity may be

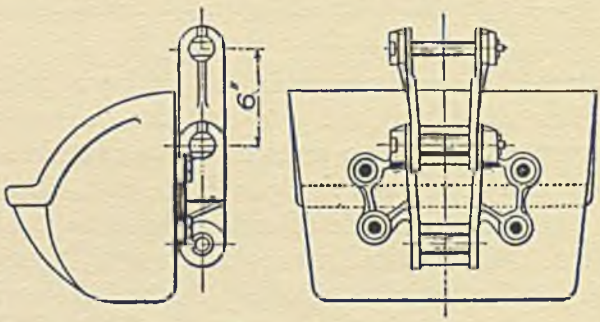


FIG. 47.—Malleable Iron Bucket Bolted to Ley Chain.

quite small. Hence it is necessary to carry large stocks of links, to enable orders to be executed quickly.

Wheels for Ley Chains.—In sprocket wheels six is the least number of teeth which should ever be used, and that number is undesirably small, giving an unequal or fluctuating speed to the chain. The longer the pitch, the slower should be the speed for smooth running. The minimum number of teeth desirable is twelve. This means a diameter of 24 inches for a 6-inch pitch chain. When wheels of small diameter are essential, the pitch should be short; whereas if large wheels are necessary a relatively long pitch must be chosen in order to avoid an excessive number of teeth.

Although for elevator chains of 12-inch pitch it is quite common to use wheels having only six teeth, yet for these long-pitch chains the motion is always very slow, rarely exceeding 80 feet per minute. If run at a higher speed the

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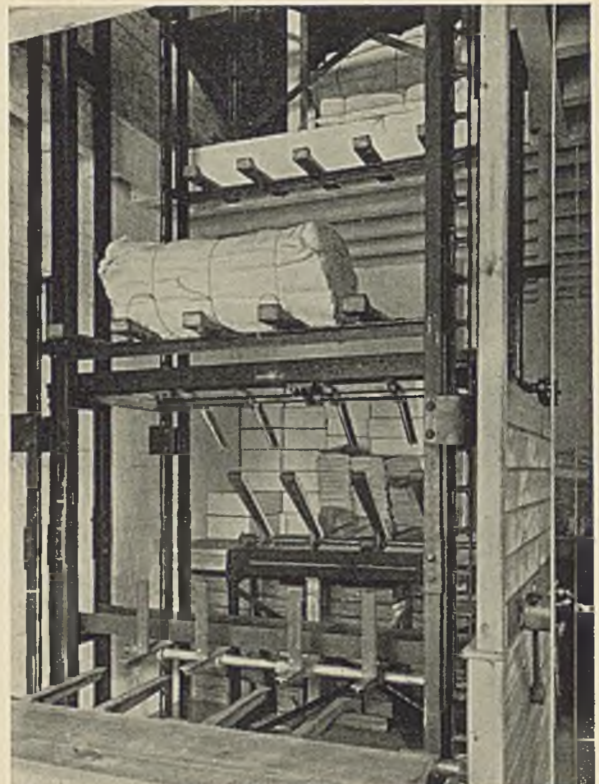
BAND CONVEYORS AT A PARCELS SORTING OFFICE.



CLOTH ELEVATOR IN A MANCHESTER WAREHOUSE.

PLATE V

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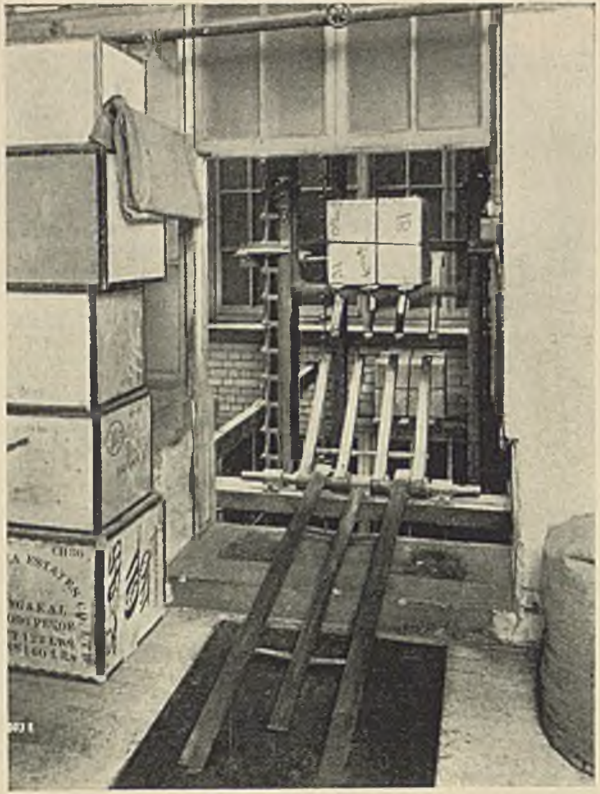
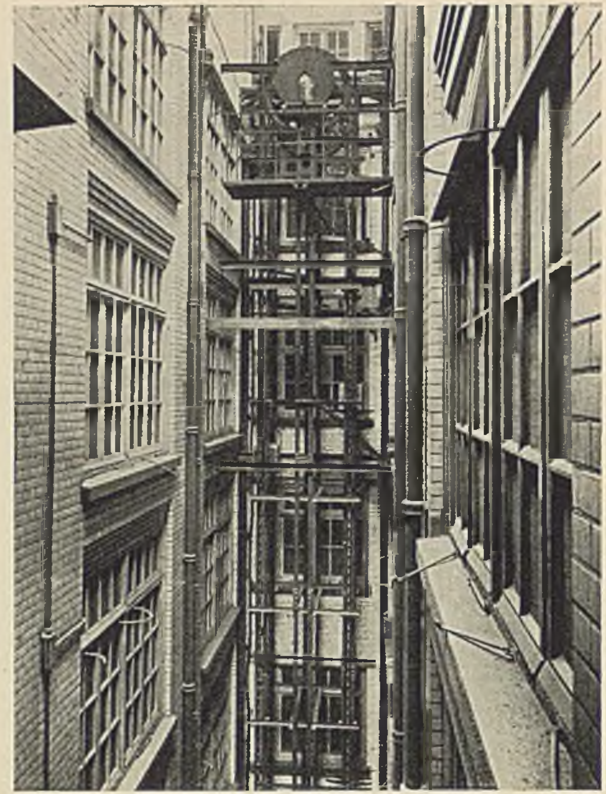
PLATE VI



DISCHARGE GRIDS OF TEA CHEST ELEVATOR.



FINGER-TRAY ELEVATOR FOR CHESTS OF TEA.

wear and tear, also the noise produced, are excessive. In such a case it is better, for the sake of durability, to use a wheel of seven teeth; whilst a really first-class job demands wheels of ten teeth, or 39 inches diameter, whenever the conditions are severe.

The one practical objection to wheels of large diameter in elevators is the considerable increase in first cost which their use entails. It is not simply a matter of the cost of the wheel itself, but the fact that everything else must be in proportion. Thus a big wheel means a heavier top shaft and bearings, a greater ratio of gear reduction between the motor and the top shaft, and a larger elevator casing, which means higher cost and more space occupied.

Hence it is a fine point to say what diameter of wheel is of maximum final efficiency, taking into account both the greater first cost of a big wheel, as compared with a little wheel, and the increased wear and tear of the latter. Generally speaking, the smaller wheel would be preferred for a cheap and perhaps temporary job, whereas a wheel of large diameter would be adopted in a first-class permanent job that would be expected to run for years without giving trouble or showing undue wear.

If for any reason a sprocket wheel of fair size is inadmissible in the case of an elevator, then it is often better to omit teeth altogether and fit a plain roller or traction wheel to both the top and the bottom shaft; thus relying on the frictional grip between the chain and the traction wheel to lift the loaded buckets. The result will be a smoother running and quieter elevator for a given bucket speed.

In ordinary chain wheels it is usual to allow a large amount of clearance between the link and two adjacent teeth; this clearance being provided to ensure that the links may lengthen a reasonable amount in wear without the chain riding on the top of the teeth, and also in order to lighten the wheel. But in the case of a special sprocket wheel where the motion may be reversed from time to time (as in a swing-tray elevator), it is usual to make its teeth with little or no backlash, so that they become much thicker than ordinary teeth.

Frequently sprocket wheels are wanted in halves, the division being made by thin parting plates placed in the mould, the two halves being bolted together and machined as a whole wheel. The advantage of a split wheel is the facility with which it can be fixed in position and removed without disturbing the shaft. Naturally, the first cost of a split wheel is relatively high.

For heavy chain wheels subjected to exceptionally severe duty, working in grit and dirt, cast manganese steel often can be used to advantage, being exceptionally durable under abrasive wear. Manganese steel wheels are not only high in first cost, however, but they also take a long time to make; and this long delay in delivery is sometimes fatal to their adoption. The difficulty of machining a manganese steel wheel can be got over by casting a soft iron bush in the boss, which bush can be easily bored out and keywayed. Such

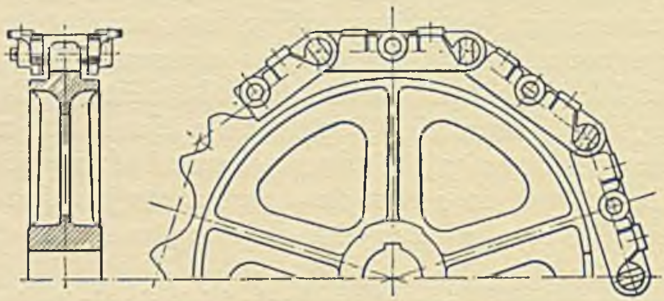


FIG. 48.—Head Wheel and Chain for Heavy Elevator.

special wheels are used to the greatest advantage with heavy Ley bushed chains fitted with manganese steel pins and liners. A steel wheel for a heavy continuous bucket elevator is shown in Fig. 48.

7. **The Dodge Cable Chain.**—This form of chain was brought out many years ago by James M. Dodge, a distinguished American conveyor-engineer and a former president of the Link-Belt Engineering Co. The links are similar to those of a crane chain but of longer pitch, being made of wrought iron and welded at the ends. The special feature of this chain is the detachable malleable iron bearing-blocks (Fig. 49) interposed between the links in order to increase the bearing surface and the durability. On these are conveniently cast at intervals suitable attachments for the reception of scrapers and other types of carrier.

The Dodge cable chain has great flexibility and will stand rough treatment and neglect better than any other type of conveyor chain. Though less used than formerly, it has been employed extensively for scraper conveyors handling

FIG. 49.—Dodge Cable Chain and Scraper.

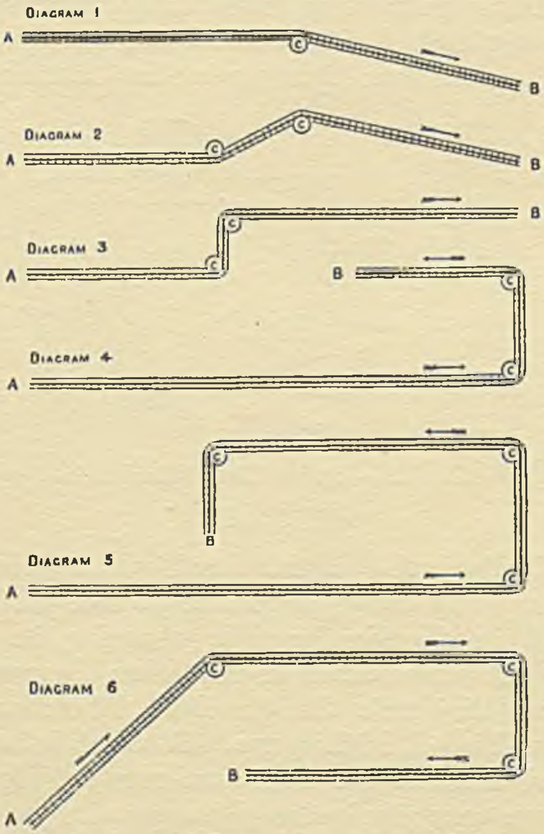


FIG. 50.—Possible Paths of Cable Chain Conveyor.

coal, for universal slat conveyors, for overhead monorail conveyors and even for bucket elevators. The line diagrams (Fig. 50) indicate various possible paths of a Dodge cable chain conveyor, the return strand of chain being run either above or below the carrying strand. Being a biflex chain the path is not confined to motion in one plane only.

The Dodge cable chain is most suitable for fairly heavy jobs, although it has been made from bars as light as $\frac{1}{2}$ inch in diameter. But there are only three sizes that have been much used, viz., $\frac{5}{8}$-inch of 6 inches pitch, $\frac{3}{4}$-inch of 8 inches pitch and $\frac{7}{8}$-inch of 12 inches pitch; the utmost working loads for which these chains are suitable being 2500, 4000 and 5000 pounds respectively. For the sake of durability it is wise to keep well within these figures.

The photographic view (Plate III) represents a small part of a remarkably flexible 21-inch slat conveyor for taking boxes of soap round multiple bends; and utilising 1170 feet

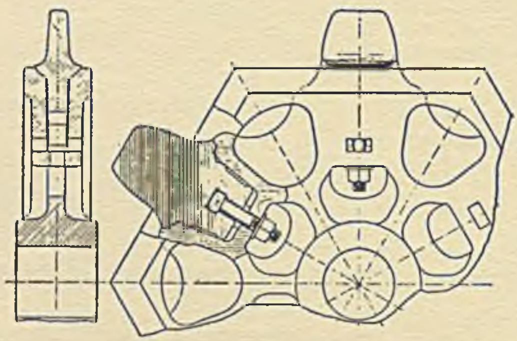


FIG. 51.—Dodge Chain Wheel with Renewable Teeth.

of $\frac{3}{4}$-inch Dodge cable chain, fitted with special side grip attachments. This conveyor runs at 50 feet per minute and is reversible in direction, besides changing its level more than once. It was erected at the Irlam Soapworks of the Co-operative Wholesale Society Ltd., Manchester, in the year 1914, and is still in daily use. Grooved deflecting wheels or idlers are fitted at the numerous corners. Another view of this unique conveyor is also given opposite page 32.

The sprocket wheels for driving Dodge cable chains usually have fixed teeth cast integral with the rim; but wheels with renewable teeth are also available, as indicated in Fig. 51. Such wheels are rather complicated and expensive, but have proved advantageous when the conditions of working are exceptionally severe. Of course it is much cheaper, both in material and labour, to renew the teeth than to disconnect an old wheel and replace it with a new one. Indeed it is often no small matter to get a wheel off a shaft that has been at work some years; as conveying plant is apt to be placed in inaccessible and dirty situations, rendering overhauling difficult to carry out.

8. **The Ewart Roller Chain.**[1]—This form of pin chain (Fig. 52) is extensively used in factories abroad for wide sugar-cane carriers (or conductors) having steel slats, whose function it is to feed great quantities of cane in a continuous stream into the ponderous crushing mills which squeeze out the sweet juice contained in the cane. In such carriers at least

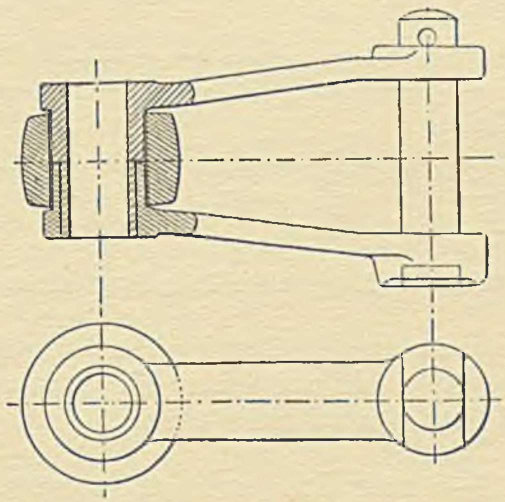


Fig. 52.—Ewart Roller Chain in Section.

two strands of chain are run in parallel, and frequently three or four strands; these needing careful "matching."

The Ewart roller chains with telescoped bosses are also utilised in the carriers for removing the crushed cane (then known as bagasse or megasse) after all the juice has been extracted by a series of crushers, from the mill house to the boiler house, where it is burnt for generating the steam consumed by the mill engines.

This type of conveyor chain is well adapted, too, for use in glass bottle continuous annealing *lehrs* and in other furnace work where the temperature does not exceed a dull

[1] In America this chain was formerly styled the Howe chain, having been invented by the late Glen Howe when associated with the Link-Belt Co.

red heat. When used for slat conveyors it is not necessary to add special supporting wheels, because the chain rollers are of fairly large diameter and travel on angle runway guides, thus forming a convenient means of supporting the chain. The rollers are made with ample clearance, to avoid all chance of binding. Plate X gives a photographic view.

The distinctive feature of this malleable chain is the rigid connexion of the two sidebars by a telescoping boss or barrel, thus giving a full bearing between the working parts and at the same time facilitating assembly. The parts are a forced fit, a drift being pressed through the hole to receive a T-headed steel pin.

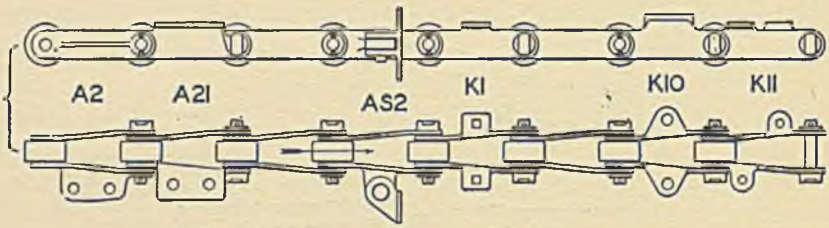


Fig. 53.—Ewart Roller Chain Attachments.

Fig. 53 is an assembly drawing showing various attachments for No. 906 chain, and Table IX gives a few technical particulars of four selected roller chains.

TABLE IX—SHORT LIST OF EWART ROLLER CHAINS

Ref. No.	Cost [1] Ratio	Pitch.	Pin Diam.	Weight of 10 Ft.	Test Load.	Some Common Attachments.
		Inches	Inches	Pounds	Pounds	
904	1·16	4·02	$\frac{11}{16}$	74	4,000	A2, AS2, K1
906	1	6·06	$\frac{3}{4}$	86	6,000	A2, AS2, K11
9060	1·22	6·05	$\frac{7}{8}$	103	8,000	A21, K10, K11
9063	1·78	6·06	1	148	10,000	K11

Miscellaneous Chains.—At this point the interesting group of chains shown in Fig. 54 may be profitably studied. The drawing neatly compares a few forms of special chains which were being made as long ago as 1904 by the Link-Belt

[1] Comparing the most usual K attachments.

Engineering Co., of Philadelphia. They are not all obsolete even to-day.

A is a cane carrier chain, made of wrought iron and accurately pitched.

B is a link and spindle chain, used for continuous bucket elevators of large capacity.

Miscellaneous Chains

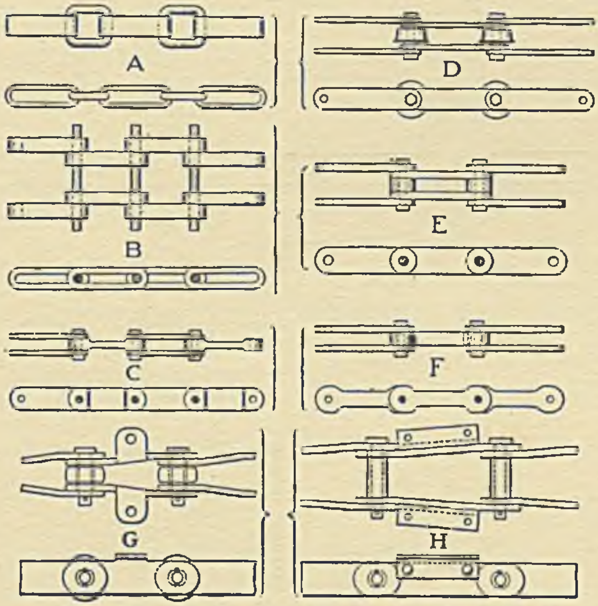


FIG. 54.—Group of Link-Belt Early Chains.

C is a steel one-and-two-bar chain, the ends of the centre links being thickened to increase the pin-bearing surface and wheel tooth contact width.

D is a two-and-two-strap link chain with rollers for long carriers.

E is a two-and-two-strap link chain with spacers instead of rollers.

F is a simple and strong steel chain of the block type.

G is a steel link roller chain with steel pin and bush.

H is a wide steel link chain with steel pin and bush but no roller for elevators.

9. **The Steel Bush Roller Chain.**—This type was originally brought out about 1880 by Hans Renold [1] as a short pitch drive chain. Much more recently it was adapted to conveyor work by lengthening the pitch and by adding attachments to the sidebars or plates. With slight variations it is now in general use for both medium and heavy duty. To be successful steel roller chains should be kept reasonably clean and well lubricated.

For quite exceptionally heavy duty this type of chain is well adapted, as there is no technical difficulty in making it of any required size and strength. For example, in a 54-inch

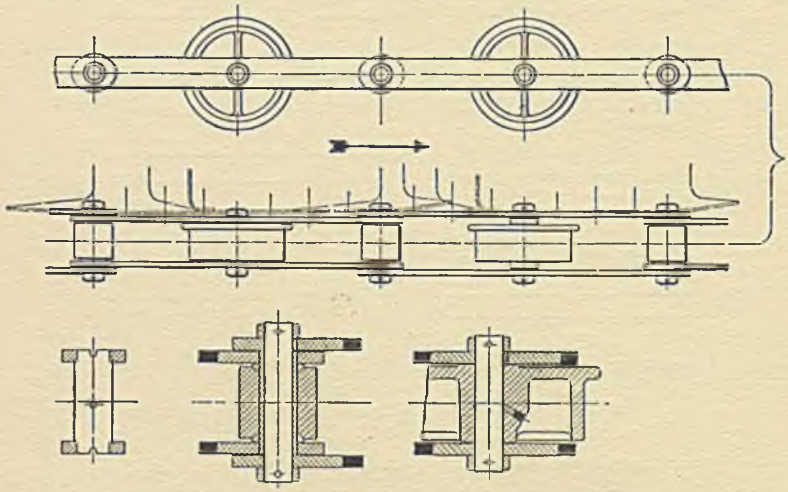


FIG. 55.—Steel Roller Chain for Giant Elevator.

continuous-bucket limestone elevator of 63 feet centres, a pair of steel roller chains of 36-inch pitch, running at 50 feet per minute, were utilised (see Fig. 55), the pins being $1\frac{3}{4}$ inches diameter.

In this case the top wheels were 72 inches diameter with six teeth, keyed on to a 9-inch top shaft running in roller bearings. Of course, this elevator was quite special and no standard chain was available. So an individual chain had to be designed and made to suit the particular job, contrary to the usual practice and only seldom necessary. As there are

[1] Though of Swiss origin, Hans Renold achieved great success in Manchester half a century ago, as the most prominent English maker of steel chains for the transmission of power.

both inner and outer links the unit length of such a chain is twice the pitch or pin centres.

Steel conveyor chains of standard design are now available in a wide range of pitches and strengths, having a variety of standard attachments integral with the sidebars. Special attachments, however, are either welded or riveted or bolted to the sidebars, or are fixed by bolts through hollow pins.

Hollow pin chains are made in breaking strengths ranging from 6,000 to 36,000 pounds, and in the case of solid pin chains from 3000 to 100,000 pounds. The solid pin type chains are intended primarily for steeply inclined elevators, whilst those of the hollow pin type are specially suitable for conveyors.

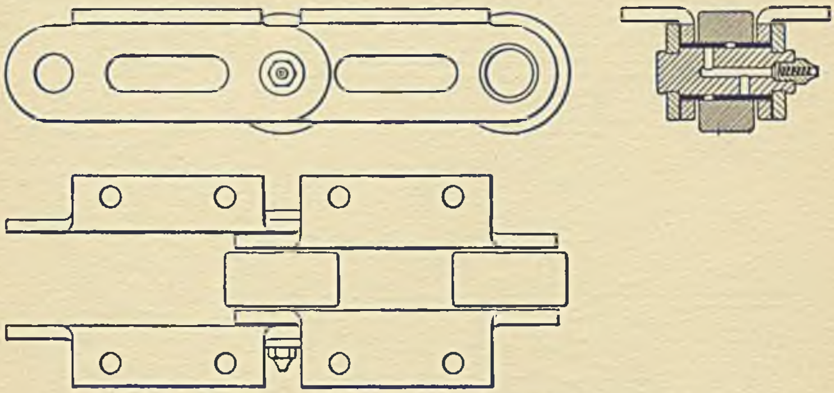


FIG. 56.—Heavy Duty Renold Roller Chain.

The latter is the lightest type of conveyor chain for a given strength and provides an easy means of carrying round cross-bars or other form of pivoted connexion.

Fig. 56 illustrates a heavy duty Renold roller chain of 6 inches pitch with K2 attachments for a sugar-cane conveyor. The chain rollers are $3\frac{1}{8}$ inches diameter, and it weighs 150 pounds per 10 feet; the breaking load being 70,000 pounds. Instead of readily removable pins being fitted the joint pins or rivets are simply forced into the sidebars and the ends slightly riveted over. The pins are drilled up for grease-gun lubrication.

10. **Combination Chain.**—This chain has malleable iron centre links alternating with flat steel sidebars, connected by removable steel joint pins. The pins have flattened ends,

securely held in flat-sided holes in the sidebars and fitted with split cotters. In order that all the sidebars may be alike, with a round hole at one end and a shaped hole at the other end, consecutive pins are inserted from opposite sides of the chain. Otherwise the sidebars would be handed, one side having all round holes and the other side all shaped holes. Clearly the unit length of this chain is *twice* the pitch of the pins.

The wide centre links are convenient for carrying all

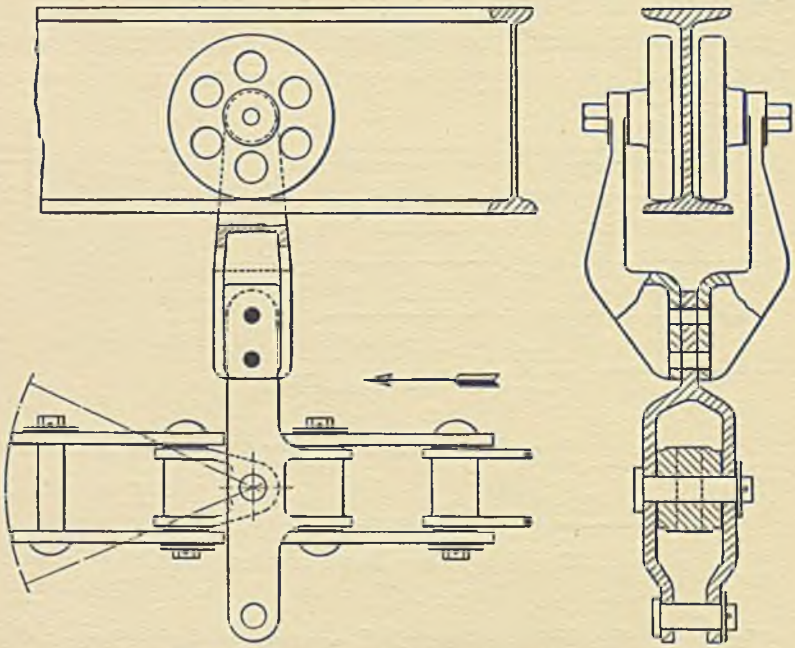


FIG. 57.—Trolley and Flexible Combination Chain.

sorts of attachments; whilst their combination with simple straight steel sidebars makes a cheap and strong complete conveyor chain much used for overhead monorail conveyors. For example, this type finds favour with the Ford Motor Company on the long conveyors at their Dagenham factory and elsewhere.

In order to make this chain flexible enough for monorail conveyors having rather sharp bends and dips, it is necessary to introduce at intervals universal joints or swivels, as shown in Fig. 57. This is a popular combination chain marked C188 of 2·61-inch pitch; the pin diameter being $\frac{1}{2}$ inch, the steel sidebars $1\frac{1}{4}$ inches by $\frac{1}{4}$ inch and the overall width $2\frac{3}{4}$ inches; whilst the working load is about 1400 pounds.

The load hanger shown is designed to suit a minimum track radius of 6 feet and a maximum slope of 45 degrees at a trolley spacing of 12 chain pitches, or about 31 inches.

11. **Drag-link Combination Chain.**—This very open type is adapted for wide drag-link conveyors, in which the

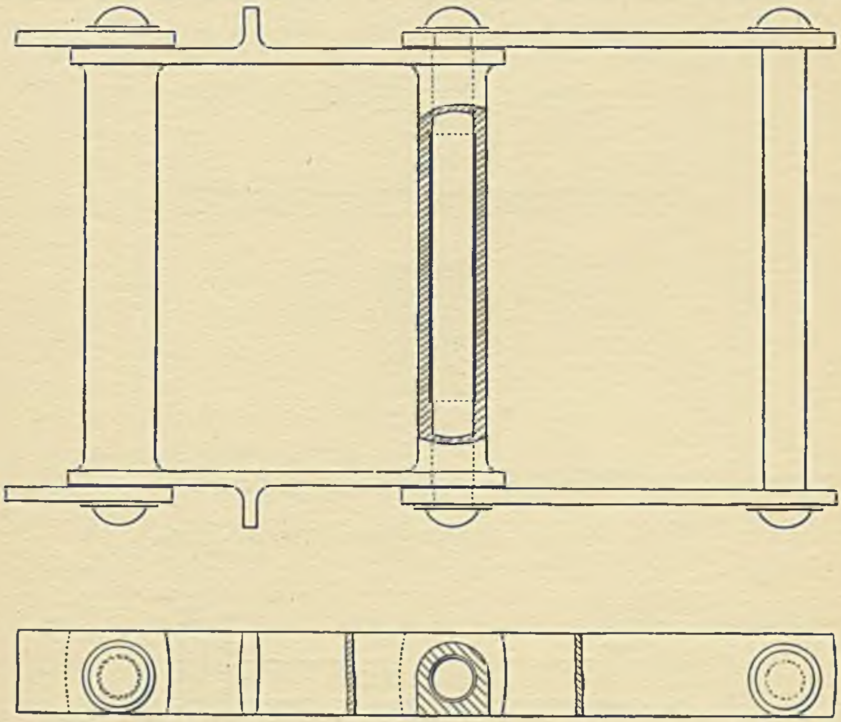


FIG. 58.—Drag-link Combination Chain.

chain is always buried beneath a mass of small material several times the depth of the chain itself, a full load being normally equal in depth of material to the overall width of the chain. The speed is generally about 40 feet per minute. Fig. 58 shows such a chain (No. 837) of 8-inch pitch, as used in a 13-inch trough. The riveted pin is 1 inch diameter and the maximum working load 7000 pounds.

12. **De Brouwer Chain.**—This type was originally brought out by the Belgian gas engineer whose name it bears; it has been used in the retort houses of gasworks for handling hot

coke more extensively than any other type of conveyor chain. It is also successfully employed in the ashes conveyors of large boiler houses, as at electric power stations. From Figs. 59 and 60 it will be noticed that the bosses of the side links are made long enough to be encircled by the wide middle links and are tied together with rivets. But the latter do not take the load in the same way that the pins do in an ordinary pin chain; the wear being on the bosses and on the sliding shoes of the centre links.

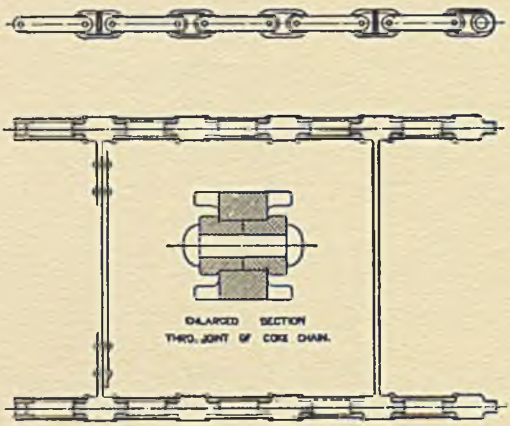


FIG. 59.—De Brouwer Coke Conveyor Chain.

FIG. 60.—Cross-section of De Brouwer Conveyor.

The De Brouwer chain is commonly built up of steel drop forgings with each crossbar integral with a pair of middle links. Sometimes the wearing parts are case-hardened, to improve the durability. Alternatively malleable iron castings are used, with flat steel crossbars riveted to the attachment links at intervals of 30 inches. Thus chains of different over-all widths can be conveniently built up by simply varying the length of the crossbars. In the original De Brouwer chain the latter were merely thin round bars[1] riveted into

[1] See Zimmer's "Mechanical Handling," vol. i, p. 154.

the middle links, and could therefore hardly be styled "scrapers."

In an actual hot-coke conveyor the chain is run until it almost drops to pieces, lasting about eighteen months on severe duty. The chain wheels have hard iron adjustable teeth,[1] permitting the pitch to be increased as the chain wears and elongates.

The conveyor trough is of substantial construction and is fitted with a renewable cast-iron bottom plate fully an inch thick. The chain is buried beneath a mass of red-hot coke, which falls upon it at intervals from the retorts as the chain slides slowly along the trough in front of the retort benches. Meanwhile water is being played on to the hot coke from a number of jets. Thus the conditions of working are extremely severe.

13. **Other Drag-link Chains.**—Though of recent years drag-link conveyors have gained a position of considerable importance in the conveyor world, space will not permit of more than a brief mention of some of the chains now fitted to them. These assume quite a variety of forms, but as a class they are relatively wide, open and shallow; sliding either in deep troughs or in closed casings and completely buried beneath the load. They are made either from flat steel bars or from drop forgings or from malleable-iron castings.

The ordinary Ewart chain has also been used with success in drag-link conveyors of small size. But a modified form of Ewart chain with a divided head has been designed specially for drag-link chains (Fig. 61). This form is neat and easily detachable.

A very old and cheap form of drag-link chain is the so-called **U**-link chain (Fig. 62) which has been much used for coal conveyors of moderate capacity. The bent steel flats are connected by shouldered rivets, whose bearing area is apt to be too small to give long life. Similar chains, up to 12-inch pitch with $\frac{7}{8}$-inch rivets, have been made for handling sawdust and refuse in sawmills.

The malleable iron "Diamond" coal chain (Fig. 63) has had an enormous vogue for some thirty-five years in the coal-face conveyors of collieries. The digging edge is seen in the cross-section. Several variations of this chain have been

[1] See Zimmer's "Mechanical Handling," vol. i, p. 154.

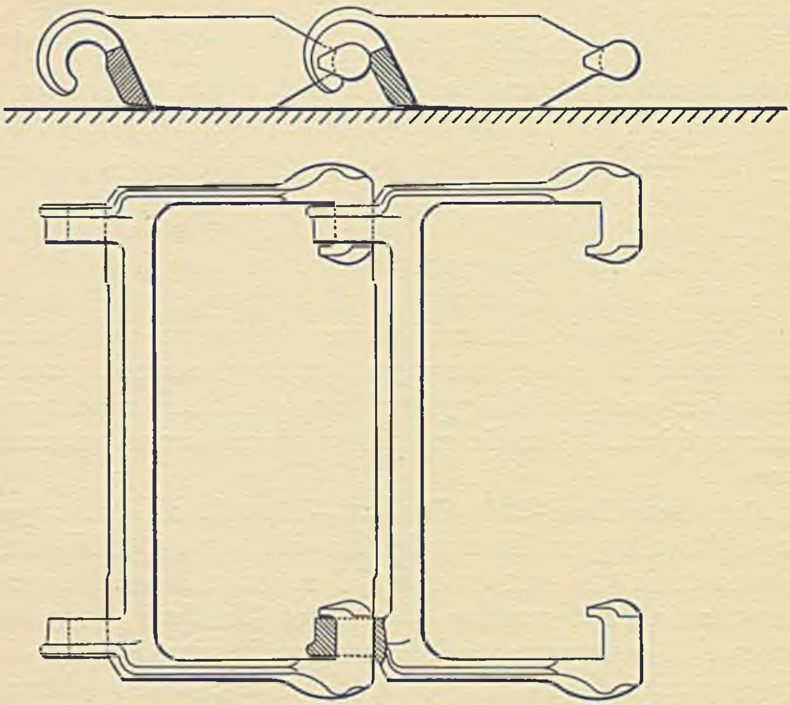


FIG. 61.—Light Ewart Drag-link Chain.

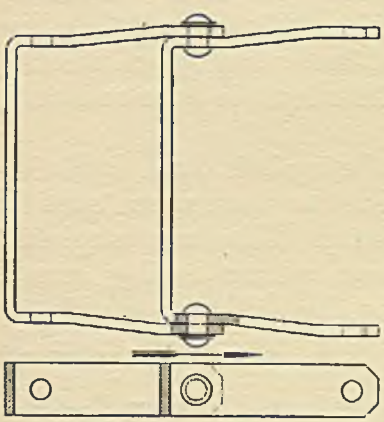


FIG. 62.—U-link Steel Conveyor Chain.

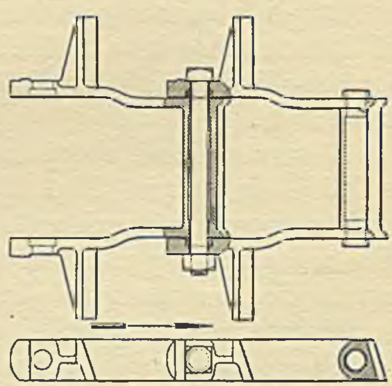


FIG. 63.—Diamond Coal Conveyor Chain, Old Type.

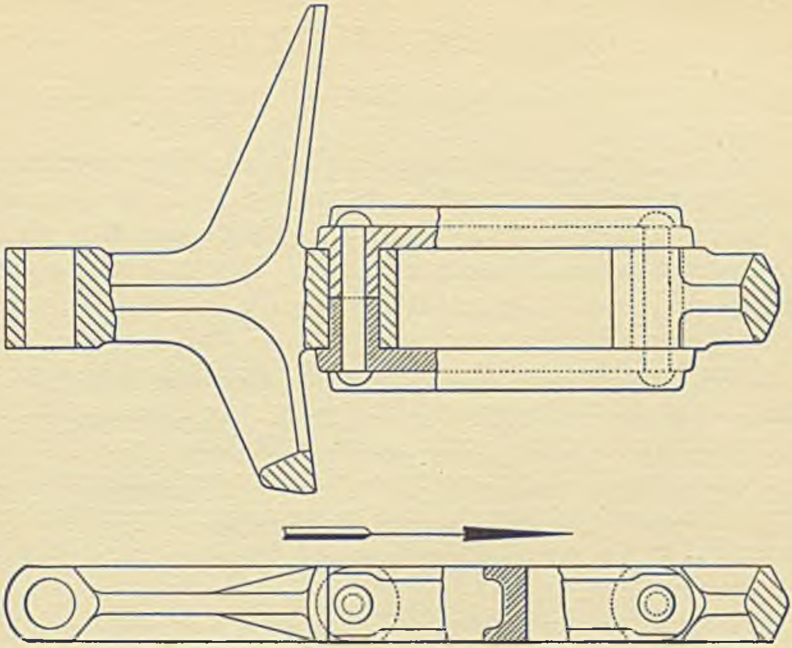


FIG. 64.—Diamond Coal Conveyor Chain, New Type.

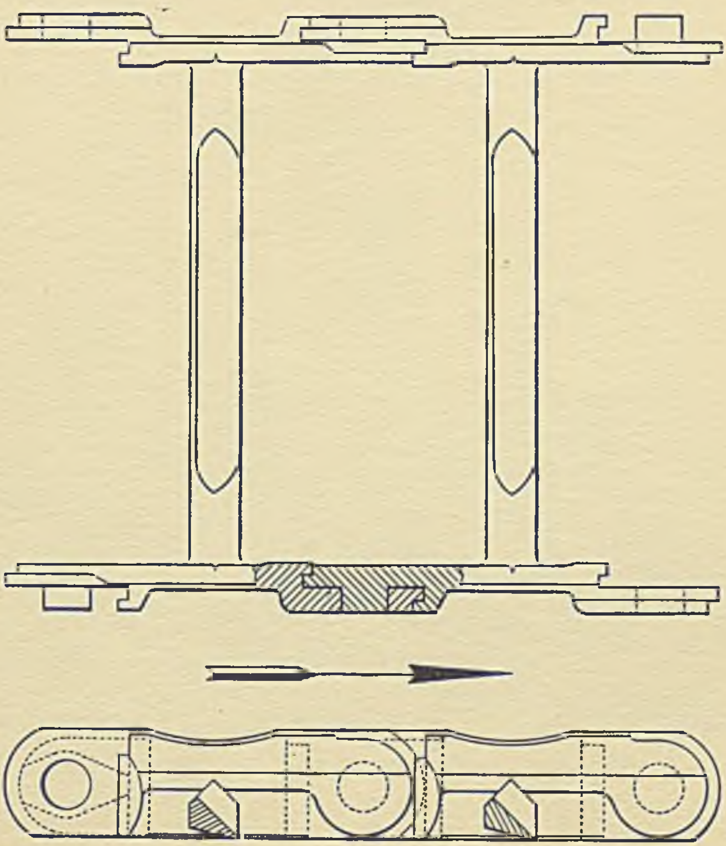
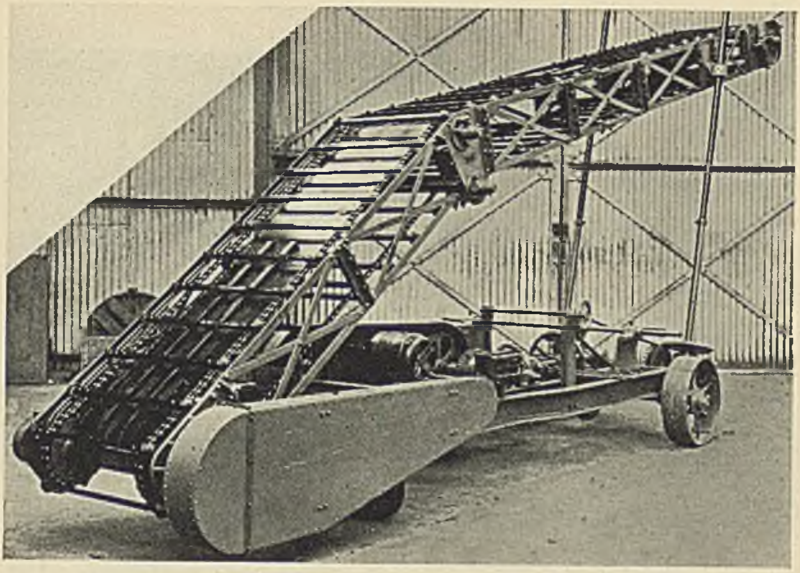


FIG. 65.—Crossbar Type of Redler Conveyor Chain.

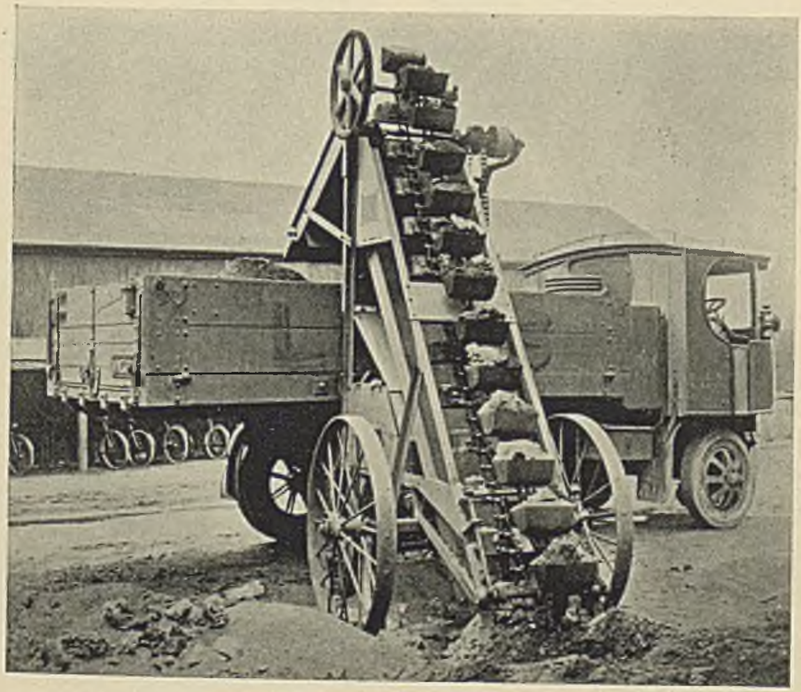
designed for the same duty, but the old pattern is still in some request.

When fitting these links together it is necessary, on account of the lateral snugs or short bosses, to spring the sidebars into position by means of a small crowbar before connecting up the links by square-headed bolts and nuts. Fig. 64 shows a more modern design of " Diamond " coal conveyor chain in which the bearing surface is much increased.

A common form of the Redler chain is shown in Fig. 65. This is the crossbar type with digging edge, as adapted for horizontal conveyors. It is made as light as possible, no pins being used. Another type with prongs is adapted for steeply inclined conveyors, and several other special forms are made.



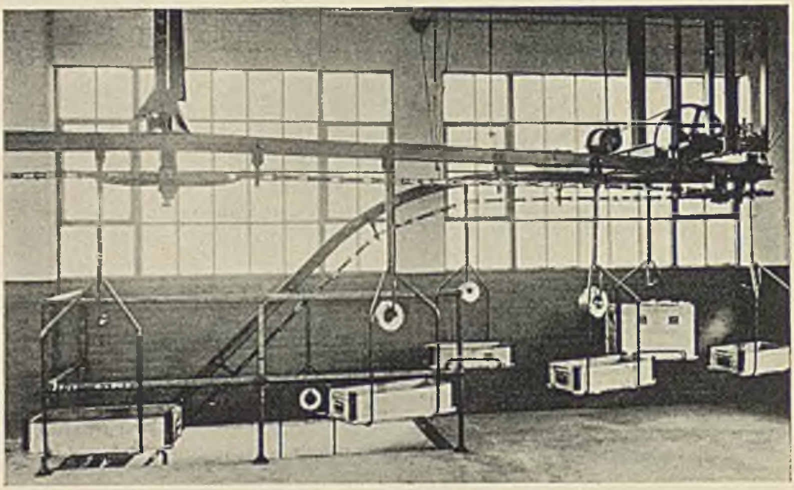
LIGHT PILER FOR 200-POUND BAGS.



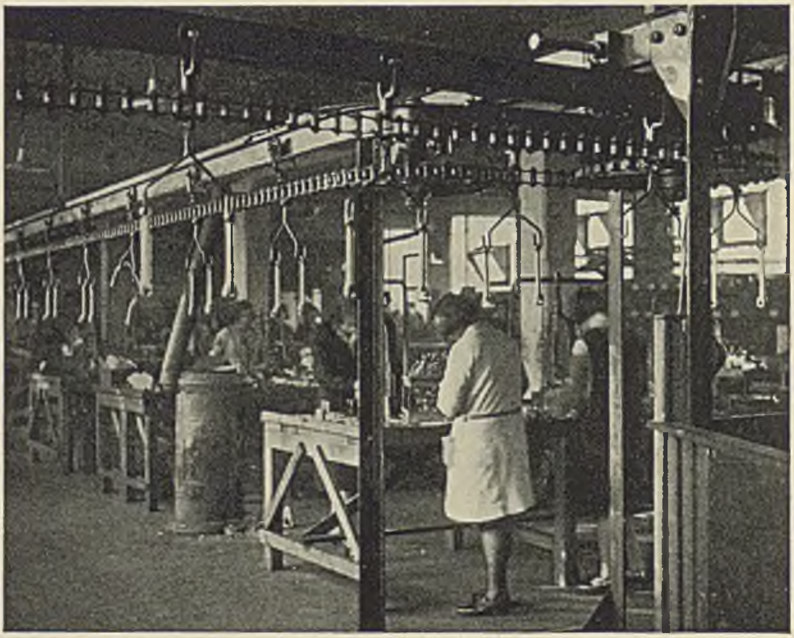
PORTABLE ELEVATOR LOADING A LORRY.

[*To face page* 80.

Plate VIII



Driving Terminal of Monorail Chain Conveyor.



Overhead Conveyor at a Bicycle Factory.

To face page 81.]

CHAPTER IX

BULK CONVEYORS HAVING HORIZONTAL OR SLIGHTLY INCLINED PATH OF MOTION (CLASS A)

1. **Steel Slat or Apron Type.**—In principle this does not differ materially from the wood slat conveyor used for bags and boxes. Fig. 66 shows in cross-section a picking belt or horizontal travelling table made for a colliery. It consists of a series of narrow steel plates or slats, from 4 to 6 feet long,

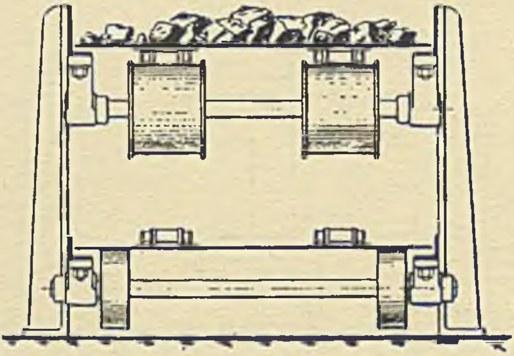


FIG. 66.—Section of Coal Picking Belt.

carried by two strands of chain, having a tension adjustment; also two pairs of chain wheels, main and back shafts, driving gearing, chain supporting rollers with shafts and bearings and the necessary supporting framing. In this case the horizontal steel angles are carried by cast-iron stands, but all-steel framing is more usual. Timber framing was formerly common but is now practically obsolete.

Cast iron as a material of construction remains in favour for gearing, brackets and bearings; but it was never much used for main supporting framing in conveyor work. Cast-iron hoppers, however, are very durable, though reinforced concrete hoppers and supports are now more in vogue, especially for storing materials like coke.

The steel slats may simply overlap about $1\frac{1}{2}$ inches, being bolted to taper lugs on the chains; or they may be joggled and bolted to parallel lugs; or, again, taper packing pieces may be used. A large overlap to the slats is an aid to clean delivery at the point of discharge.

The large lumps of coal and the stony rejections are picked

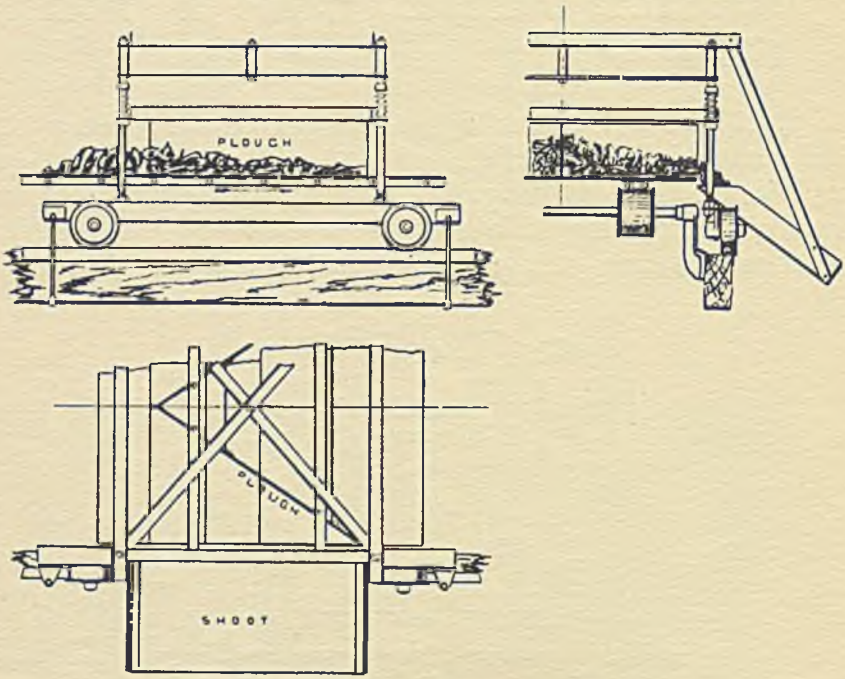


FIG. 67.—V-plough for Steel Slat Conveyor.

from this belt by hand as it moves slowly along at a speed of about 40 feet per minute. The residue left on the belt passes on to the screening plant for classification into the various commercial sizes of coal.

When it is desired to discharge coal from a slat conveyor at intermediate points instead of at one end only—as when filling a hopper—a plough is arranged to push off the coal at any point. A V-shaped travelling plough for a slat conveyor 5 feet wide is shown in Fig. 67. This discharges coal on both sides of the conveyor.

In a somewhat similar manner it is possible to discharge bags, bales and boxes from wood slat conveyors; but for these the plough is usually a board placed diagonally right across the conveyor and made easily removable or else hinged so as to be quickly put into operation or thrown out of gear at pleasure. Of course, a V-shaped plough would be quite unsuitable for discharging bags. Discharge ploughs are also applicable to belt conveyors as an alternative to trippers.

2. **Steel Tray or Pan Type (Endless Trough).**—A tray conveyor is a very suitable and durable means of carrying coarse material in bulk from one point to another, as a rule, but occasionally the load is received at several points. Though its path of motion can be partly horizontal and partly inclined, it must run in a straight line in plan view. It can be made of great carrying capacity, even when run at the usual slow speed of about 80 feet per minute, and it is economical in power consumption. The usual range of width is from 10 to 36 inches. As regards length, few tray conveyors exceed 500 feet between the centres of the terminal shafts; but at least one conveyor of 800 feet centres has been made, carrying 150 tons of iron-ore briquettes per hour.

The tray conveyor bears some resemblance to a lobster's back, with its numerous articulations. It consists of a series of overlapping pressed steel trays with turned-up sides bolted to an endless chain (having a tension adjustment at one terminal) running over a pair of chain wheels keyed on the main and back shafts, together with one or two countershafts and a train of reducing gears at the driving terminal.

A simple steel framing carries a number of supporting rollers with their shafts and bearings. Thus the mechanism of a tray conveyor is quite simple and as nearly foolproof as possible.

In comparison with a steel slat conveyor of the same width the capacity of a tray conveyor is much greater, and there is less risk of spilling some of the load; yet the details are much the same in both types, apart from the trays. These are not always made from steel plates, as occasionally for special duty malleable iron cast trays are adopted.

It is of historical interest to note that the first tray conveyor was brought out as long ago as 1880 by the late Sir Francis Ley, Bart., having been erected at the Nine Elms Gasworks, London, for the purpose of carrying coke a distance of 400 feet from the retort house, across a yard and a street, and delivering it into barges on the River Thames. It ran for fully twenty-five years. This conveyor proved a successful innovation, and so fully justified its installation that many other gasworks followed the lead set at Nine Elms.

In that initial example the chain used was of the Ewart detachable type, but nowadays Ewart chains are used only for very small light tray conveyors. Where space is limited and the duty light, one can use a 4-inch pitch chain such as No. 94, and wheels of say 12 inches diameter. Yet it is rare to use a chain of less than 6-inch pitch for even a small tray conveyor, and No. 500 Gray chain of that pitch is preferable.

Large chain pitches mean big diameter wheels, otherwise the motion becomes too jerky and the wear is heavy. When the conditions permit of terminal wheels of at least 24 inches diameter, it is best to select a chain of 12-inch pitch, thus minimising the number of trays. A favourite chain for tray conveyors is No. 612 Ley bushed chain, and the heavier No. 1200 chain has given excellent service in numerous important plants.

Generally speaking, a single strand of heavy chain is more durable than two strands of light chain, and there is seldom any real need to adopt two strands unless the required carrying capacity is very abnormal, when one naturally utilises two strands of a standard chain simply as a manufacturing convenience instead of designing a special chain.

Tray conveyors are well adapted for carrying lumpy materials like coal, coke, briquettes, stone, ores, coarse ashes and clinker. They are less suitable for moving very fine material, which is apt to leak through the spaces between the trays in spite of the overlap of an inch or more. Yet tray conveyors are used in chemical fertiliser factories for superphosphate of lime in various degrees of coarseness. For handling this clinging material it is bad practice to carry the return trays over rollers bearing on the inside of the trays, as in Fig. 68, because it sticks to the rollers. It is found better to support the return trays with their edges bearing on flanged rollers, as in Fig. 69, though at first sight this certainly does not look a promising method as regards durability.

There are several ways of supporting the trays and a corresponding variation in the designs of conveyor framing to suit these different methods. Years ago, when the Gaston type of chain, with open links and T-head pins, was extensively used, it was customary to run the chain over a series

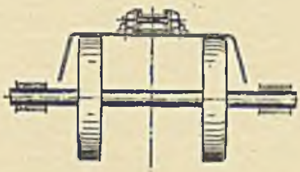


FIG. 68.

FIG. 69.

Rollers Supporting Return Trays.

of double-flanged cast-iron supporting rollers; the wide, flat bearing surface of the chain distributing the load over the whole width of the roller, thus avoiding any grooving action.

When the Gray and the Ley types of chain, with narrow sidebars, were adopted for tray conveyors, a local grooving of the flanged supporting rollers took place in course of time, and the life of ordinary cast-iron rollers was not long under heavy duty. To increase the durability the supporting rollers were made of hard chilled metal, but wear still took place on the sidebars of the chain links.

In order to avoid any wear on the chain other than at the

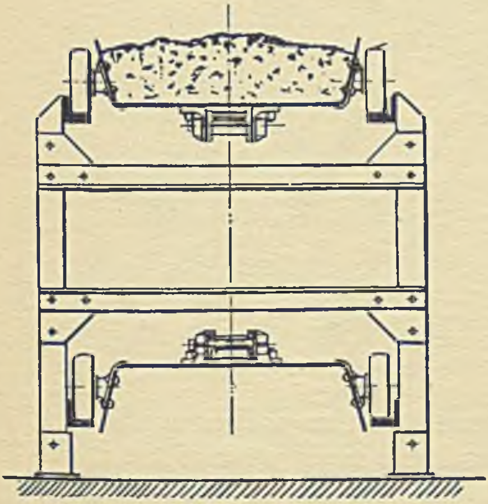


FIG. 70.—Trays Fitted with Side Rollers.

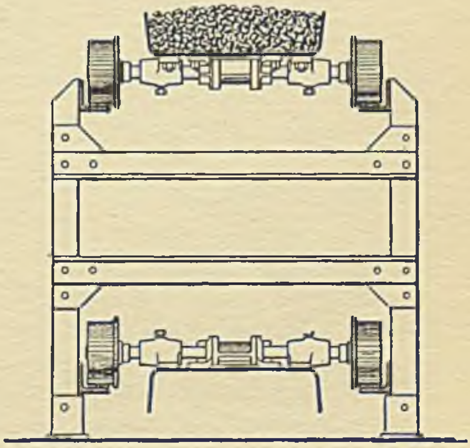


FIG. 71.—Conveyor with Through Roller Shafts.

joints, it is best to support the trays independently of the chain, as by riveting either stamped steel or cast malleable brackets on the sides of the trays, carrying travelling rollers running on angle tracks, as in Fig. 70. This change involves

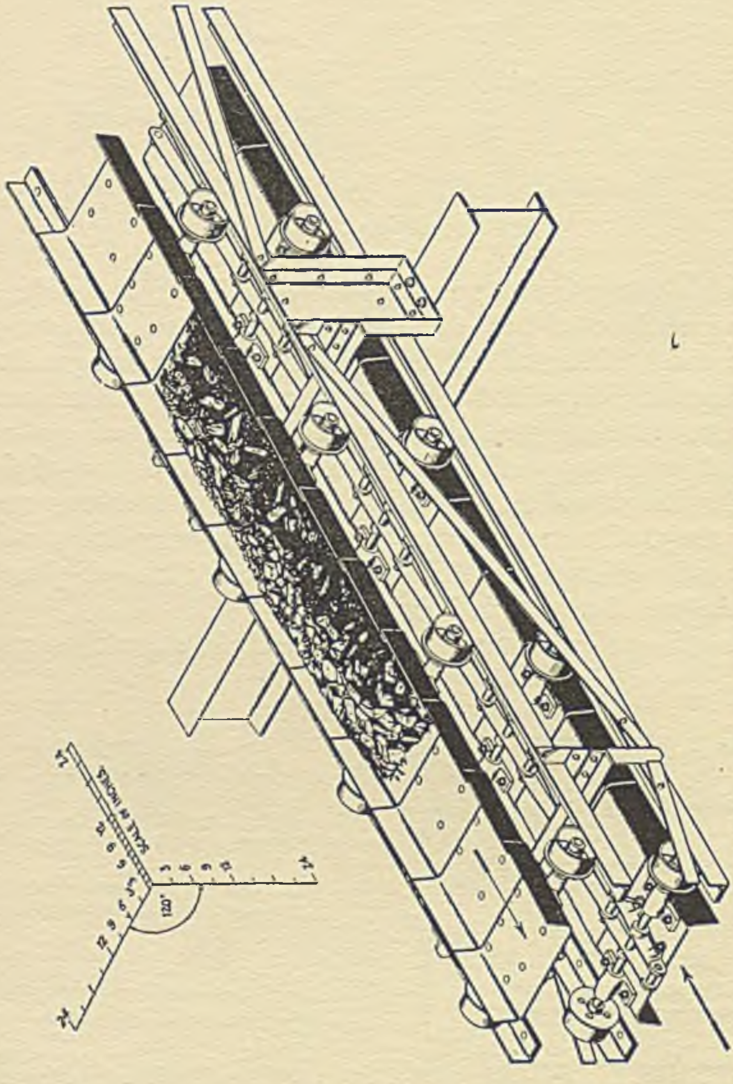


FIG. 72.—Isometric View of Tray Conveyor.

lattice steel angle framing instead of either timber or channel iron longitudinal beams. In order to avoid wear of the main angles, it is a good plan also to fix steel flats on the trackways by means of countersunk headed bolts, though this is not always done when travelling rollers are fitted. Indeed, in the case of very light and short conveyors, it suffices to skid the trays on angle tracks by projecting skidder bars bolted to the bottoms of the trays.

The best type of tray conveyor for heavy duty is that shown by Fig. 71 in cross-section and by Fig. 72 in isometric perspective. In this design travelling rollers revolve on axles passing through clearance holes in the sidebars of the chain links and fixed by brackets to the tray bottoms. In the perspective view the lumpy material being conveyed is not shown distributed over the whole of the trays, as in practice it would be, but it has been drawn for clearness over a section of six trays only. Conveyors of this design give excellent results in practice; the trays being made of pressed steel plate from $\frac{3}{16}$ to $\frac{3}{8}$ inch thick, according to the magnitude of the load and nature of the duty demanded. A suitable chain is Ley's No. 1200 K2D.

An objection to the ordinary type of fixed tray conveyor for some purposes (such as filling storage bins) is that the delivery of the load is feasible at one point only, and not at intermediate points. To overcome this drawback various tipping tray conveyors[1] have been designed, the trays being hinged to spindles carried by two strands of chain external to the trays. These tipping tray conveyors are very satisfactory for certain duties, but are naturally less simple and more expensive than conveyors with fixed trays.

3. **Band or Belt Conveyors.**—A very widely used alternative to the tray conveyor is the belt conveyor, a type which has greatly increased in relative importance and size during the last quarter of a century, being quiet-running, light in weight and economical in power consumption. It is also suitable for both the lightest and heaviest loads. Commonly a rubber and canvas belt runs over a pair of end-drums or pulleys and is supported at intervals by a series of rollers (known as "idlers") arranged to shape the belt into the form of a continuous shallow trough. Besides woven wire, other materials often used for belts are cotton, which is very pliable, and balata, which is the reverse.

Thin Sandvik charcoal steel bands are sometimes applicable. Flat steel belt conveyors are especially suitable for handling sticky clinging materials like suet, raw sugar and

[1] See Zimmer's "Mechanical Handling." vol. i, pp. 108-110.

clay. They are also employed for the transport of dry sand cores in the coreshops of modern foundries engaged on light repetition work.

Probably the widest steel belt conveyors in the world are a pair, each 12½ feet wide, erected at the Thames refinery of Tate & Lyle Ltd., London, for handling and storing cube sugar. These run at a very slow speed, so slow indeed that the motion is hardly perceptible.

Probably the largest troughed belt conveyors for coal in the world (those at Baltimore coal-shipping pier) have 60-inch 12-ply rubber belts 2225 feet long, running at fully 500 feet per minute, each driven by a 300 horse-power motor through tandem main drums 74 inches diameter.

In England probably the largest coal conveyors, having a maximum rated capacity of 2000 tons per hour, are those erected in 1926 by Fraser & Chalmers Engineering Works at the Beckton Gasworks of the Gas Light and Coke Co., adjacent to the River Thames.

On the pier are eight electric jib cranes, each fitted with a 4-ton coal grab, which lift the coal from colliers alongside and discharge it upon two 54-inch conveyor belts, running parallel with the river and meeting in the centre of the pier. Here a large hopper receives the coal from both conveyors and feeds a single cross conveyor running at right angles to the river, which normally takes it to the concrete storage bunkers ashore.

Alternatively the coal can be diverted from the cross conveyor and dropped into barges lying underneath the pier, for transport by water to other London depots of the same Company.

Suitable automatic Avery weighing machines are installed for checking the amounts of coal shown by the bills of lading and also the loads put into the barges. Each of the weigh-hoppers has the large capacity of 10 tons of coal.

When fitted with a travelling throw-off carriage or tripper (Fig. 73) a belt conveyor can deliver material at any point desired. Sometimes, however, a travelling plough (or "plow") is more convenient to apply for intermediate discharge, besides being cheaper.

The application of trippers is very old, but more recent is the alternative method of utilising a slowly reciprocating or reversible shuttle belt conveyor, discharging from each end alternately into overhead storage bins or hoppers. Such a device permits of the mixing in uniform layers of different cargoes of coal in the retort house of a gas-works, thus ensuring the discharge of a coke of regular

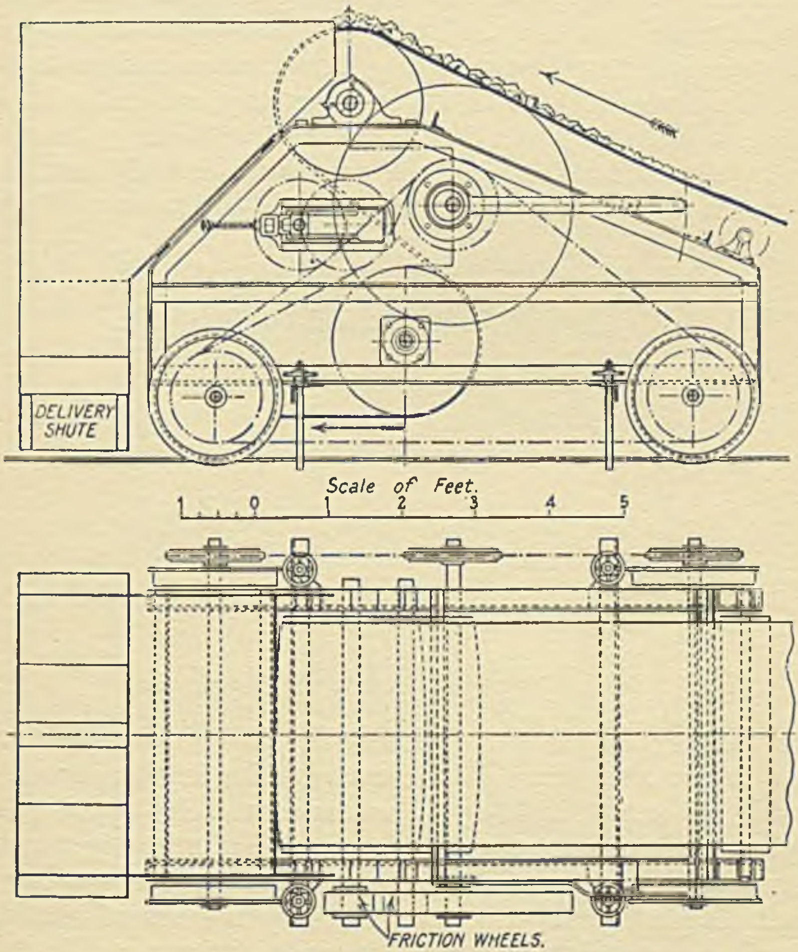


FIG. 73.—Tripper for Belt Conveyor.

structure and quality from a long range of retorts. See Frontispiece.

Fig. 74 is the cross-section showing the supporting rollers of a short inclined belt conveyor made for a colliery to handle 120 tons of small coal per hour at a speed of 300 feet per minute. More commonly three-roller troughing idlers are fitted. Shallow troughing is preferable to deep troughing on the score of durability. Ball bearings are an advantage.

In order to get maximum *durability* out of a conveyor belt it should be run flat and not troughed at all; whereas to get maximum carrying *capacity* out of a belt of given width it should be deeply troughed, thus reducing the first cost of the belt and its idlers. To get a reasonable compromise between low first cost and low maintenance charges a belt should be run with shallow troughing only, otherwise its life will be relatively short.

In like manner, to get the maximum *capacity* out of a given belt it has to run at a high speed—up to, say, 800 feet

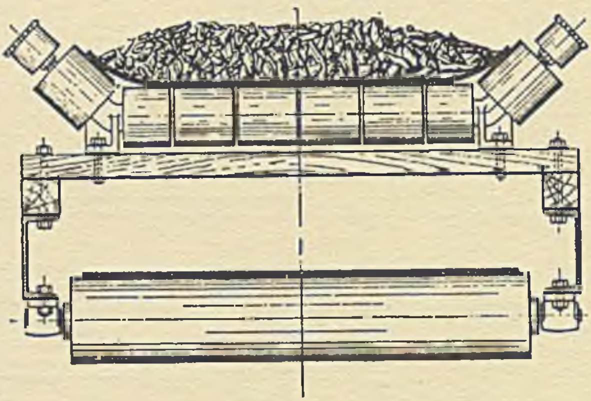


Fig. 71.—Section of Belt Conveyor for Coal.

per minute; but to get maximum *durability* it should be run at a rather slow speed. The compromise in this case is to install either a variable speed motor or variable speed gears, and to run the belt at as slow a speed as the hourly requirements permit; the highest speed being kept in reserve to meet the peak load. Thus the dual requirements of relatively low first cost and high durability are, as far as possible, both satisfied.

As regards the relative capacity of wide belt conveyors, it is noteworthy that the tonnage capacity does not vary in simple proportion to the width, but as the square of the width. Thus a 48-inch belt will carry four times as much coal as a 24-inch belt at the same speed, both being fully and uniformly loaded. Yet the wide belt might well be run at a higher speed than the other, and it will also accommodate much larger lumps of coal. Actually a reasonable hourly duty for a 48-inch belt at 500 feet per minute would be 500 tons of coal as against only 80 tons for a 24-inch belt running at 300 feet per minute.

Thus a very wide belt run at a high speed would have an enormous carrying capacity; a much greater capacity in fact than is feasible in any other type of conveyor. Speeds must not be so excessively high that fine material would be blown off the belt by contact with the air, but in this respect wide belts are advantageous.

The limit of inclination of a belt conveyor is about 20 degrees, depending on the nature of the load raised. Lumps are apt to roll off. Below that angle the capacity differs little from that of a horizontal conveyor, but it is wise to reduce the speed by 20 per cent. at 10 degrees angle and by 30 per cent. at 20 degrees angle.

A rough empirical rule for finding the carrying capacity (expressed in cubic feet per hour) of a horizontal wide troughed belt conveyor, at a speed of 100 feet per minute, is to square the width of the belt in inches and multiply by three. Then the tonnage capacity is deduced by dividing this result by the number of cubic feet in 1 ton of the material handled and multiplying by the ratio of the actual speed to 100.

For example, when handling bituminous coal slack measuring 45 cubic feet per English ton, the capacity of a 54-inch horizontal belt conveyor running at 500 feet per minute is

$$\frac{3 \times 54^2}{45} \times \frac{500}{100} = 972 \text{ tons per hour.}$$

When handling anthracite coal, measuring 23·6 cubic feet per ton, the capacity of the same belt conveyor works out to 1850 tons per hour.

The Link-Belt Company varies the factor from 2·8 for a 12-inch belt to 3·3 for a 54-inch belt, instead of using the constant multiplier 3.

In Table XVI of Hetzel's book, "Belt Conveyors and Belt Elevators," there is an instructive comparison of seven rules for calculating the power needed to drive belt conveyors. Nine special cases are considered, the belts ranging from 12 to 54 inches wide, some being horizontal and others inclined.

The materials handled are coal, coke, ore, sand, gravel and stone.

In practice it is best to calculate the several items separately in each case and then add them together. However, for a first approximation a convenient rule for the horse-power (applicable to grease-lubricated idlers) is 2 per cent. of the tons per hour for every 100 feet of length plus 1 per cent. of the tons per hour for every 10 feet of vertical lift, or thus—

$$\text{Horse-power} = \left(\frac{\cdot 02\text{L}}{100} + \frac{\cdot 01\text{H}}{10}\right)\text{T}.$$

For example, a 24-inch belt conveyor of 500 feet centres with a rise of 60 feet and a load of 200 tons of coal an hour will absorb, say,

$$\left(\frac{\cdot 02 \times 500}{100} + \frac{\cdot 01 \times 60}{10}\right)200 = (\cdot 1 + \cdot 06)200 = 32 \text{ horse-power.}$$

This rough-and-ready rule is not applicable for materials lighter than 25 or heavier than 125 pounds per cubic foot.

4. **Flight or Push-plate or Scraper Conveyors.**—A scraper conveyor is specially convenient when its load has to be delivered at several intermediate points, as when filling storage bins in the retort house of a gasworks, also in boiler houses of moderate size. Though there is no difficulty in making such a conveyor to handle 100 tons of coal an hour, the usual range of capacity is from 5 to 50 tons an hour (see the isometric view, Fig. 75).

A scraper conveyor may be either horizontal or inclined, or it may be partly horizontal and partly inclined. It consists of a series of scrapers or push-plates bolted to one or two endless chains, sliding inside either a steel or a cast iron or a wood trough; the upper or return strand of chain being supported either by idler wheels or by skidder bars and continuous guides. By providing suitable openings in the trough, fitted with sliding doors, the load pushed along by the scrapers can be delivered at any one chosen point, or part of the load may be discharged at one point and part at another point simultaneously. In large conveyors of this type rollers are usually fitted to the scrapers, running on angle tracks. Early forms of scraper conveyors had pressed-steel troughs with steel scrapers sliding therein, but these

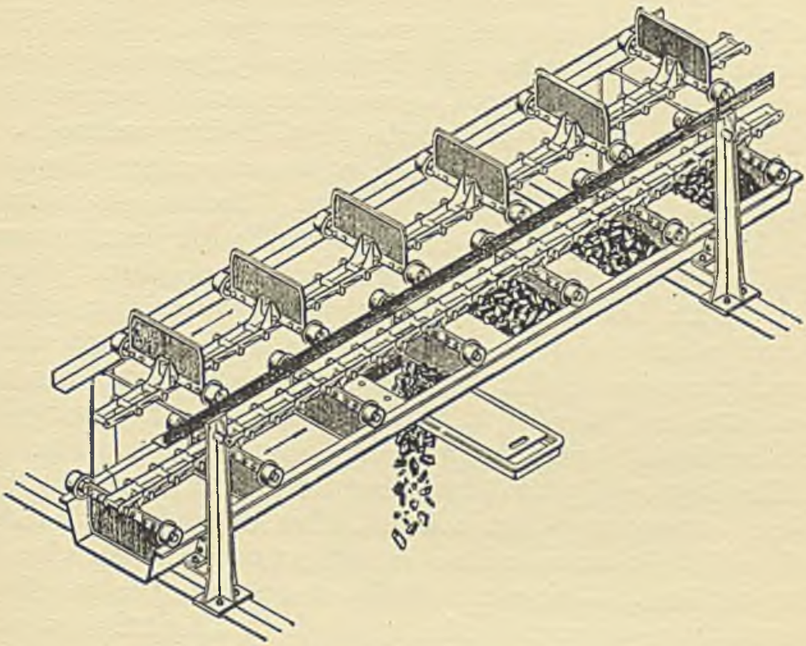


FIG. 75.—Isometric View of Scraper Conveyor.

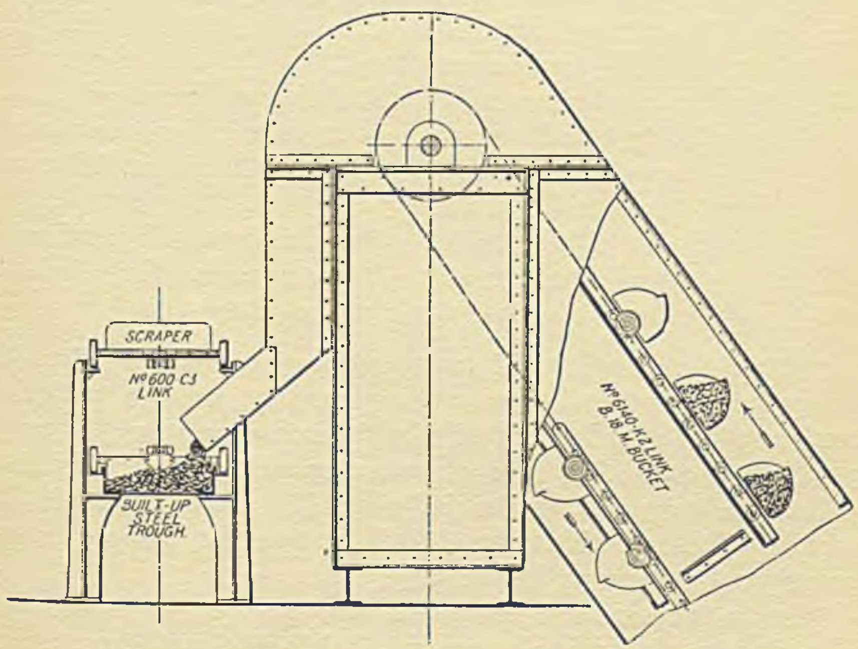


FIG. 76.—Section of Scraper Conveyor Fed by Elevator.

were noisy. The noise was reduced by bolting hard wood backs to the steel scrapers, or wood troughs were used. The wear and tear on the bottom of steel troughs is fairly severe, hence it is advisable to line such troughs with renewable lining plates. Rollers greatly reduce both friction and noise.

Fig. 76 represents in section a 50-ton scraper conveyor distributing coal into storage hoppers. The trough is built up of steel plates and angles, and is fitted with $\frac{1}{4}$-inch renewable lining plates. There is a clearance of about $\frac{1}{2}$ inch between the bottom of the trough and the scrapers, which are bolted to malleable-iron crossbars having turned ends, carrying cast-iron rollers fitted with oilless carbonated bushes. The latter are intended to eliminate all oiling or greasing by utilising the lubricating properties of compressed graphite.

The best method of lubricating conveyor rollers is a moot point, because coal-dust collects, cakes on and may render useless all lubricators, unless more than ordinary attention is given to them. Besides the simple oil-hole and the use of an oil-can, there are several other methods of lubricating rollers, viz. :—

(*a*) To put grease lubricators on every roller.

(*b*) To fit lubricators to the ends of the spindles, which may be bored up.

(*c*) To use hollow rollers containing oil wells.

(*d*) To apply oil reservoirs and wipers giving a constant supply of oil to the rollers, but this is liable to be wasteful of oil.

(*e*) To fit either ball or roller bearings and tecalemit grease-gun nipples. Then attention for lubrication is necessary only at long intervals.

The old and well-tried scraper conveyor is still capable of doing good work without causing anxiety, though perhaps somewhat out of fashion. Probably it is more nearly foolproof than any other type of conveyor adapted for multiple-point discharge, a feature in which it excels. Yet it is certainly less suitable than the belt type for a very long conveyor and for very big duty.

As an experienced American conveyor engineer (F. V. Hetzel) remarks,[1] when comparing belt and chain conveyors :

[1] See his " Belt Conveyors and Belt Elevators," p. 205.

" In many places, boiler houses especially, a flight conveyor makes the best distributor even though it does take more power to run it. The older forms of flight conveyors were noisy, but modern roller flight conveyors or roller-chain conveyors are nearly noiseless. They are strong and rugged, easy to load, easy to discharge, spill less dirt outside, and they will work under bad conditions where a belt will fail. Some engineers have a prejudice against scraping coal in a trough. It does take more power, but it does not hurt the coal ; and as for the wear on the trough, the item of replacement is not an important one. It is a fact that in plants like breakers in the anthracite coal region and tipplers in bituminous districts,[1] chain conveyors are used far more than belt conveyors."

5. **Drag-link Conveyors.**—The drag-link conveyor is a convenient and popular type with which the name of Arnold Redler has been so prominently connected as an assiduous experimenter and pioneer that it is often referred to as the Redler conveyor. To some extent drag-link conveyors have superseded the older worm conveyors, though both types should be avoided for handling lumpy materials. They are more suitable for moving powdery and granular substances. Paddle-worm conveyors, however, are cheap and effective for moving and mixing clinging materials.

Compactness is an attractive feature of both drag-link and worm conveyors. They are readily supported and can be placed either horizontal or inclined at a moderate angle. Long-worm conveyors should never be employed, as the power required to drive them is excessive and any want of alignment causes serious trouble. On the other hand, drag-link conveyors are economical of power and are certainly more efficient than worms for long conveyors.

The diagram (Fig. 77) refers to the case of a drag-link conveyor having several feed openings on the top and multiple discharge openings or outlets on the bottom of the casing. It is suitable for handling a powdered material like bicarbonate of soda. All the outlets except the last one as indicated are

[1] On the other hand, when I visited South Africa in 1935 I found that belt conveyors were predominant in both the gold and the coal mining industries of the Transvaal ; whereas chain conveyors were all but universal in the sugar factories of Natal.

fitted with doors to control the various openings through which the powder falls on the return run.

In such a case the chain selected might be, say, No. 430 of 6-inch pitch, 10½ inches wide and 1¼ inches deep. This could be actuated by a 12-inch sprocket wheel, through suitable reducing gearing, to give a speed of 40 feet per minute to the chain enclosed within a relatively deep casing

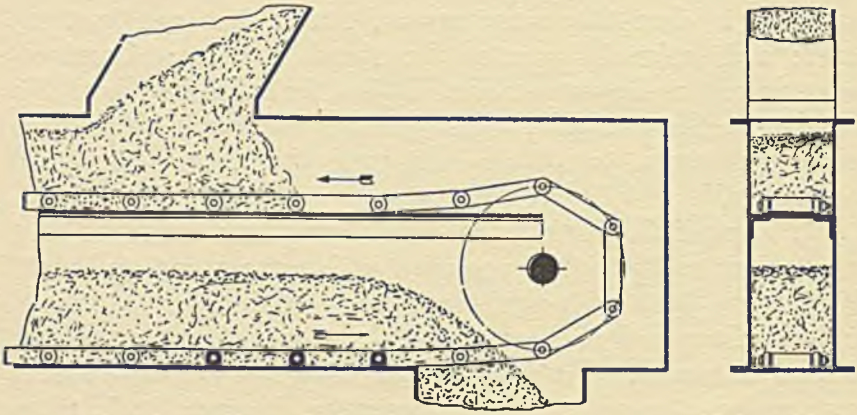
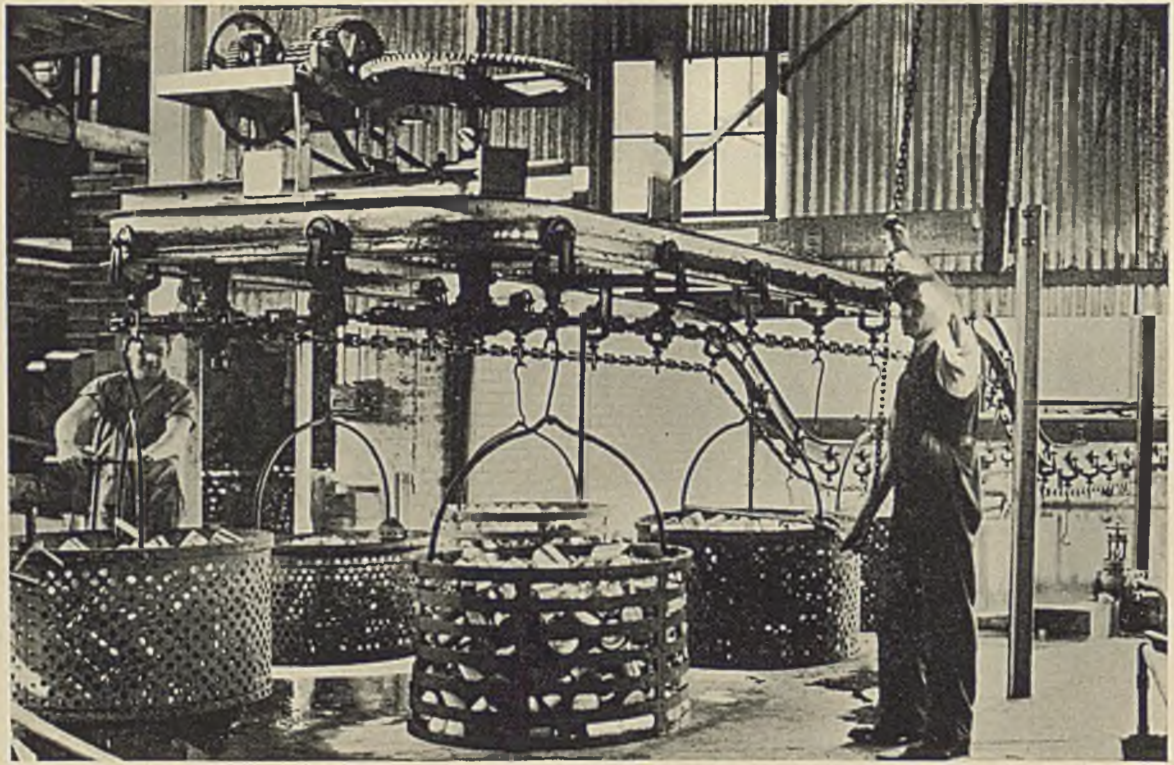


FIG. 77.—Sections of Drag-link Conveyor.

11 inches wide and $\frac{3}{16}$ inch thick, fitted with bottom plates ¼ inch thick. See also Plate XI, facing page 112.

In another and simpler case the fine material being handled, such as small coal, could enter a somewhat less deep casing by a single inlet at the top, then fall through the skeleton chain on to the bottom plate, and be carried along in a deep stream until it reached a single outlet kept permanently open.[1] Numerous modifications and alternatives are possible, each conveyor being designed to suit the particular conditions called for.

[1] See Zimmer's "Mechanical Handling," vol. ii, p. 862.



UNIVERSAL CONVEYOR AT A CANNING FACTORY.

PLATE IX

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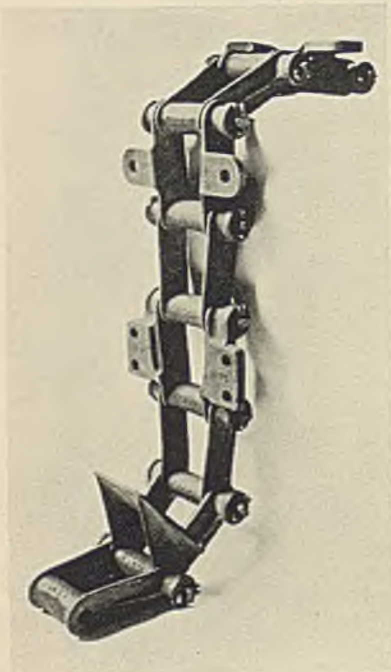
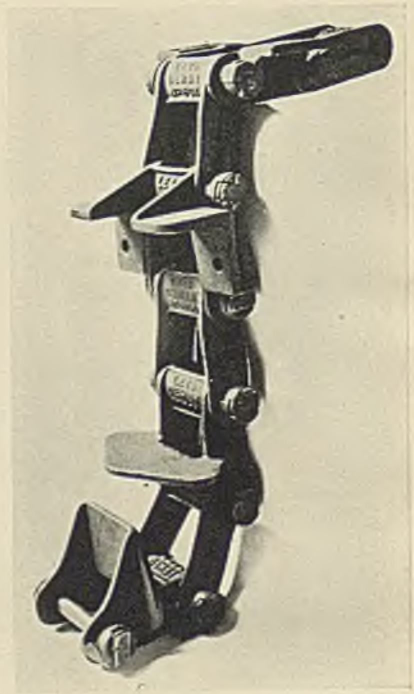
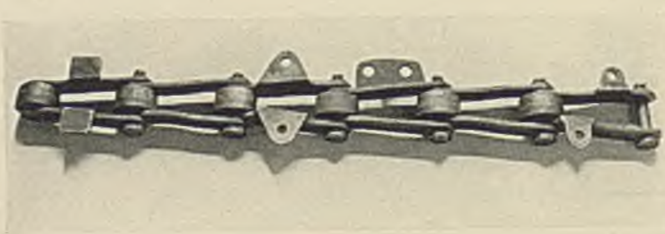
PLATE X



GRAY PIN CHAIN.



LEY BUSHED CHAIN.



EWART ROLLER CHAIN.

To face page 97.]

CHAPTER X

THE DISCHARGE OF BUCKET ELEVATORS

THE most critical point in the operation of a bucket elevator is undoubtedly the delivery or discharge point. Although the load may be perfectly picked-up in the boot and taken in full buckets to the top of an elevator, yet if a large part of the material is spilled and falls down again to the bottom, instead of being discharged in a clean manner, the elevator is obviously very inefficient; for not only is it delivering below its full capacity, but it is wasting power and probably also causing needless dust and dirt.

Hence it is a question of much practical importance to consider the factors governing a good discharge from an elevator, these being :—

1. The nature of the material lifted.
2. The shape of the buckets which hold the material.
3. The speed at which these buckets travel.
4. The diameter of the top wheel.
5. The inclination of the elevator.
6. The position of the delivery chute in relation to the buckets during the discharge period.

Nature of Material Lifted.—It is obvious that some materials will flow into and out of buckets much more readily than others. Grain is an example of a freely flowing material with a low angle of repose. Rounded bodies, such as beans, nuts and pebbles, also flow more freely in mass compared with angular bodies like granite chips.

On the other hand, small coal containing a large percentage of dust will hardly flow at all when damp. Other difficult substances are moist oxide of iron, anthracene crystals, clay and mud of various degrees of consistency.

Perfectly dry and fine substances like sand will flow freely, but damp moulding sand on the contrary is of a clinging nature. Many sticky substances are prone to hang up in chutes and to cake on the interior of buckets, thus reducing their capacities and necessitating periodical cleaning out. Fibrous materials are also a source of trouble. Thus a conveyor engineer must ever be on the alert to avoid the pitfalls which beset him when dealing with such a variety of materials as are encountered in practice.

Shape of Buckets.—The ordinary household bucket, designed for carrying *water*, is of much simpler geometrical

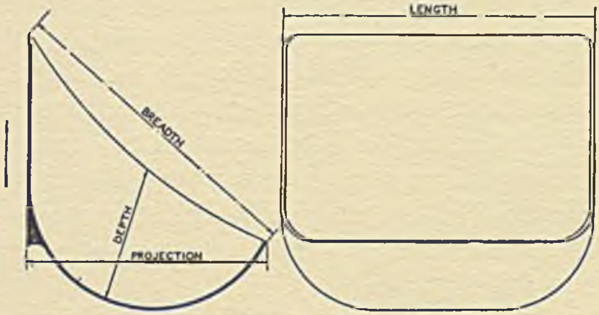


FIG. 78.—S-type Bucket for Pulp.

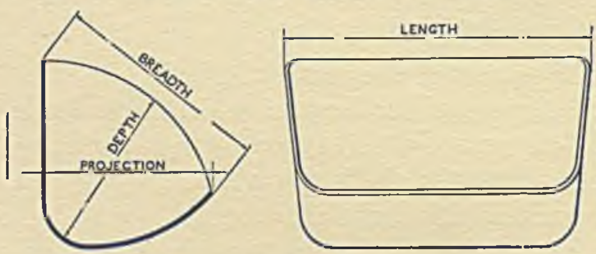


FIG. 79.—C-type Bucket for Sugar.

form than an elevator bucket, being a hollow truncated conical vessel. A domestic *coal* bucket or coal scuttle is less symmetrical in form than a water bucket, being shaped with a view to the easy discharge of its contents ; but it is still widely different in shape from an elevator bucket.

The actual shape of an elevator bucket varies greatly according to the material to be lifted. For viscid materials the shape more nearly resembles that of a shovel or scoop than a water bucket. Fig. 78 shows a shovel-like bucket (S-type) designed for lifting sticky substances and fibrous pulp. Its well-rounded shape is noteworthy. There are no sharp corners, the only flat part being the back, which forms a seating where the bucket is bolted to a chain attachment link of the **K**-type. This freedom from angularity of the bucket is all to the good in facilitating a clean discharge of its sticky contents.

A rather more shapely design of bucket is type **C**, shown in Fig. 79; which is suitable for lifting sugar, flour, wood-pulp and other light but semi-sticky substances. Here the relative depth is increased and the corners are not so well rounded as in the **S**-type, but the capacity is greater for a given length. Shallow buckets have only a small carrying capacity.

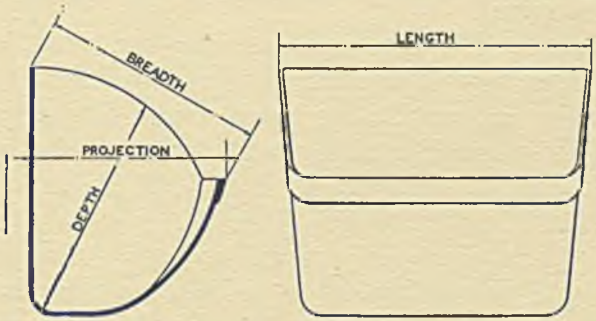


FIG. 80.—B-type Bucket for Coal.

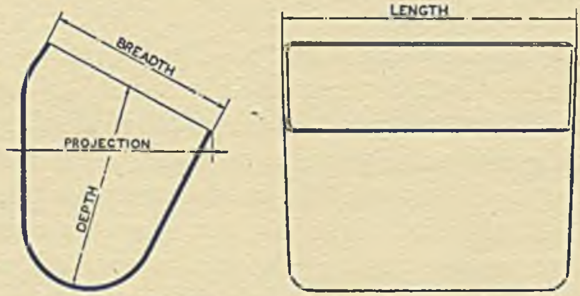


FIG. 81.—F-type Bucket with Angle Back.

Capacity of Buckets.—Bearing on the subject of capacity it is an important geometrical fact that the volumes of similar bodies of any shape, however irregular, vary as the cubes of any chosen linear dimension; so that the capacities of geometrically similar buckets vary as the cubes of their lengths. Thus a 12-inch bucket will hold eight times as much as a 6-inch bucket, if the two buckets differ only in scale. Similarly, by cubing the length ratio, it is seen that the capacity of an 18-inch bucket is twenty-seven times that of a 6-inch bucket of similar form.

But, of course, in practice actual buckets of the same type are not all precisely similar in geometrical form, partly for manufacturing reasons. In a regular series of commercial buckets the ratio of capacity in cubic inches to the square of the length is more nearly constant than the ratio of capacity to the *cube* of the length. Moreover, the actual holding capacity of an individual bucket of normal shape depends partly on the inclination of the elevator of which it forms a part; whilst the capacity of a series of such buckets is inversely proportioned to their pitch or distance apart at a given lineal speed.

In the case of a slow-running elevator, whether vertical or inclined, a type **B** bucket with a long back (Fig. 80) is advantageous in preventing premature discharge of the contents. It is much used for coal elevators. An application of this bucket is depicted in Plate XIII. A cranked or "angle-back" bucket, type **F** (Fig. 81), is even better in this respect, and is frequently used on steep elevators. For avoiding spill this delay-action or discharge-lag is specially important in vertical elevators of the double-strand dump type described later. The buckets have parallel ends, to suit the chain attachments.

Position of Delivery Chute.—By deflecting the return strand of a vertical elevator it is possible to arrange the delivery chute vertically below the path of discharge and so get a clean gravity-discharge, even though the buckets may be moving at a slow speed. As an alternative to the deflecting wheels, which make the best job, one may use curved guides and skidders on the return strand; a method which it is necessary to adopt in the case of single-strand dump elevators.

For loads exceeding, say, 100 tons an hour the writer's own preference is for a *pair* of single-strand inclined elevators, each one of moderate capacity, rather than a single exceptionally big elevator; the latter necessitating chains of double-strand, which need to be carefully "matched" in the first instance and kept properly matched throughout the whole life of the elevator, if severe racking stresses are to be avoided and freedom from breakdowns ensured. Alternatively, swivel attachments to the buckets can be adopted with great advantage. There is also great practical convenience in being able to run either elevator of a pair independently, instead of being entirely dependent on one special elevator fitted with details of exceptional dimensions (not usually kept in stock) whose temporary failure might cause enormous loss of production and prove disastrous to a business.

In a recent case of an almost vertical single-strand elevator, handling phosphate rock, trouble was experienced by the late discharge of material from the buckets; the capacity in consequence falling far below the expected 50 tons per hour, at a bucket speed of 140 feet per minute. Without altering the speed the difficulty was overcome and the desired capacity attained mainly by raising the top shaft a foot higher above the discharge chute; thus allowing rather more time for the buckets to empty their contents *into* the chute, instead of *beyond* it, and so preventing the material dropping down into the bottom boot, as was previously happening.

Thus the designer of an elevator should never overlook the importance of considering with some care the relative position of the delivery chute and the buckets during the discharging period. It is much better to allow an excessive drop than too little; even though it may mean a slightly longer elevator.

Bucket Speed.—The best speed for a particular elevator, when discharging its load by tilting its buckets as they pass over the top wheel, depends on a variety of factors. These include the nature of the material raised, the inclination of the elevator, the pitch of the chain and the diameter of the top wheel.

Generally speaking the speed should be high for light materials like grain and slow for heavy minerals and clinging substances. For temporary service speeds may legitimately be higher than for permanent service. The faster the speed and the smaller the top wheel the cheaper the elevator becomes in first cost, but the shorter its life, other things being equal; slow speed and durability going together. As a rule, vertical elevators run considerably faster than inclined ones, in order to get a clean centrifugal discharge.

Actual bucket speeds vary from 1 foot per second to 4 feet per second in *chain* elevators, and up to 10 feet per second in *belt* elevators. A common speed of 6-inch pitch chain for inclined coal elevators is 2 feet per second or 120 feet a minute, using a sprocket wheel of 2 feet diameter having twelve teeth. For continuous overlapping buckets on a 12-inch pitch chain the usual speed is 70 feet per minute, using a top wheel of at least six teeth. If higher speeds are required to get the capacity, the top wheel should be larger in diameter, say, 36 inches, thus diminishing the shock and noise arising from the pulsating action of long-pitch chains when working on sprocket wheels of few teeth.

When a variable-speed drive is installed it is easy to adjust the speed of an elevator to give the best discharge under varying conditions ; but on account of the initial cost this refinement is usually omitted.

The Dynamics of Bucket Elevators.—Before going on to describe examples of bucket elevators suitable for vertical

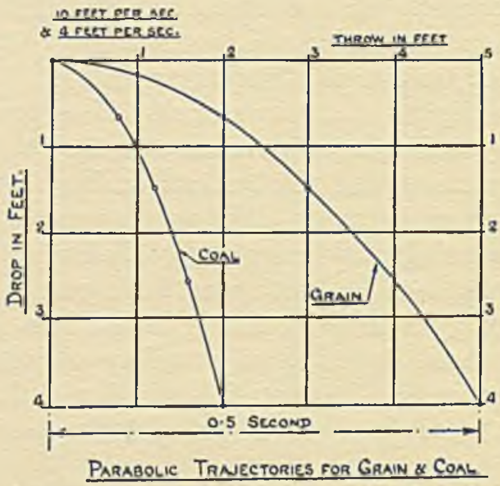


FIG. 82.—Curves for Quick and Slow Discharges.

and steeply inclined path of motion, it will be instructive to consider certain dynamical principles which have an important bearing on the design of centrifugal discharge elevators.

The first of these principles is that every body, owing to its inertia, either continues in its state of relative rest or perseveres in its state of uniform motion in a straight line, except in so far as it is compelled by external forces to change that state. This is Newton's first law of motion, slightly amplified.

Suppose, for example, that a grain of wheat (Fig. 82) has just left a bucket, as it turns the top centre of a vertical elevator, with a horizontal velocity of 10 feet per second. By reason of its inertia or its momentum the grain tends to go straight on at the velocity of projection, but is prevented from doing so by two forces, viz., the resistance of the air (which is here negligible) and the attraction of the earth or gravity, which is of paramount importance.

The result is that the grain of wheat describes a curved trajectory, which is well known to be a parabola. The horizontal distance of the grain from the origin is at any instant given by the product of the uniform velocity into the time. Thus at the end of half a second the grain will have travelled

$$10 \text{ feet/second} \times \cdot 5 \text{ second, or } 5 \text{ feet.}$$

This is the horizontal displacement of the grain.

But the vertical displacement or drop of the grain by the action of gravity is $\frac{1}{2} gt^2$; which becomes

$$\tfrac{1}{2} \times 32 \times \cdot 5^2, \text{ or 4 feet for half a second's fall.}$$

Thus we get the lowest point (Fig. 82), and the other points on the curve are found in the same way, taking intervals of a tenth of a second.

In like manner we get the trajectory for a small piece of coal discharged from a bucket with a horizontal velocity of 4 feet per second. The vertical drop is the same as for the grain of wheat, but the rate of throw being so much less, a far steeper trajectory results. This fact closely affects the position of the discharge chute, which should be placed lower down in a coal elevator than in a grain elevator. As a matter of fact, the main discharge would also take place further round the quadrant of the circle in the case of the slower-running coal elevator.

The precise moment at which a piece of coal would leave a bucket is influenced by the friction of adjacent pieces of coal and also by the shape of the bucket. It has been assumed that the material in the buckets, whether grain or coal, is dry and fairly free-flowing.

The second fundamental dynamical principle is that the inertia resistance of a body is directly proportional to the mass of the body and to the rate of change of its velocity.

So, in absolute units, force = mass × acceleration ; and in gravitation units, $\text{force} = \frac{\text{weight}}{g} \times \text{acceleration}$. This is Newton's second law of motion.

Thus, if a ton of coal is set in motion and acquires a speed of 2 feet per second in one second, then the force required to do this will be

$$\frac{2240}{32}\times 2=140 \text{ pounds.}$$

This inertia resistance or starting effort is one of the things that has to be taken into account when calculating

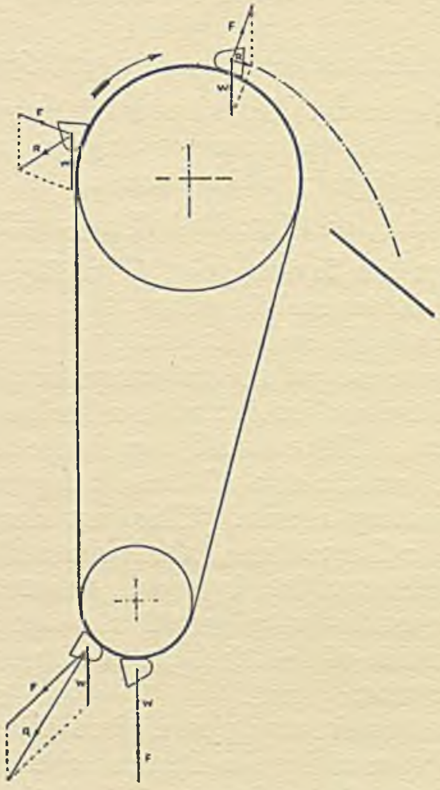


Fig. 83.—Diagram showing Resultant of Vertical and Radial Forces.

the initial horse-power required to drive an elevator with full buckets. The other important items are the gravity horse-power and the friction horse-power, and there are others. It is best to calculate all the items separately and then add them together.

Now consider the motion of a body revolving in a circular path, such as a loaded bucket going round the top wheel or head pulley of an elevator (Fig. 83). It can be shown that the radial acceleration of the body towards the centre of rotation is directly proportional to the square of the linear velocity and inversely proportional to the radius of the path, or

$$a=\frac{v^2}{r}.$$

Hence it follows that the radial force maintaining the body in its circular path is the product of the mass into the acceleration, or

$$F=\frac{w}{g}\times\frac{v^2}{r},$$

in gravitation units.

This centre-seeking or centripetal force is equal and opposite to the outward pull or centrifugal force. The term

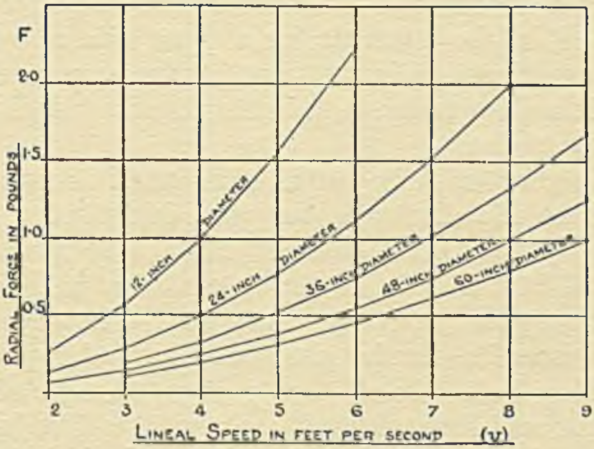


Fig. 84.—Graphs of Radial Forces.

radial stress might be used to cover both the action and the reaction in question.

Referring to Fig. 84, the series of curves exhibit the result of plotting the radial force at various speeds for a body weighing 1 pound when moving in circles of various diameters ranging from 1 foot to 5 feet. It will be seen that the influence of the diameter of the wheel is very important; the radial force being equal to the weight at a speed of 4 feet per second for a 12-inch circle and at 8 feet per second for a 48-inch circle, and so on for other sizes. These represent the highest speeds that should ever be adopted even for vertical belt elevators handling grain, unless the head-pulley diameters are increased accordingly.

The speeds determined by equating weight and radial force, however, are quite excessive for handling coal and other minerals. High speeds are especially bad for coal, because of the breakage caused at the discharge chute and the heavy wear and tear on the latter.

Fig. 83 indicates at two chosen points on the upper circle the resultant R of the vertical W and radial forces F in the case of a 48-inch head pulley when W and F are equal. This will be at a lineal speed of 8 feet per second, corresponding to about 38 revolutions per minute of the head shaft.

The lower circle indicates R in the case of a 24-inch foot pulley, when F is twice W. At the bottom centre $R = W + F$ and is a maximum. W represents the weight of 1 pound of material in a bucket, and is constant both in magnitude and direction; F is also constant for a given size of pulley and speed in magnitude only, but not in direction. Hence the resultant R varies greatly both in magnitude and direction as the buckets revolve.

The direction of R is just as important in relation to the pick-up as to the discharge, for with free-flowing materials the surface of the bucket contents tends to lie normal to the direction of R. Clearly in the case shown in Fig. 83 the pick-up is very bad, as no grain can remain in a bucket until the latter leaves its circular path and fills under gravity only on the rising belt. Small foot pulleys, though cheap and compact and too often adopted, are a great evil in high-speed elevators. It is more difficult to get the grain into the buckets than out of them.

As regards the time of discharge from the buckets, in relatively low-speed elevators the main discharge begins to take place when the radial component of W is equal to F in magnitude, regardless of the inclination of the elevator itself; except in so far as the point of discharge is affected by the shape of the buckets.

Thus in Fig. 85, when the radial force $F = \frac{1}{2}W$ and θ is the angle sought, $\sin \theta = \frac{F}{W} = \frac{1}{2}$.

The required angle at discharge is, therefore, 30 degrees to the horizontal.

The other half of Fig. 85 also represents the exceptional case when the radial force is twice W, as in a super-high-speed elevator. The forces are balanced and discharge from the buckets will begin to take place when the vertical component of F equals W in magnitude.

If ϕ is the angle sought,

$$\text{Cos } \phi = \frac{W}{F} = \frac{W}{2W} = \tfrac{1}{2}.$$

Therefore, $\phi = 60$ degrees.

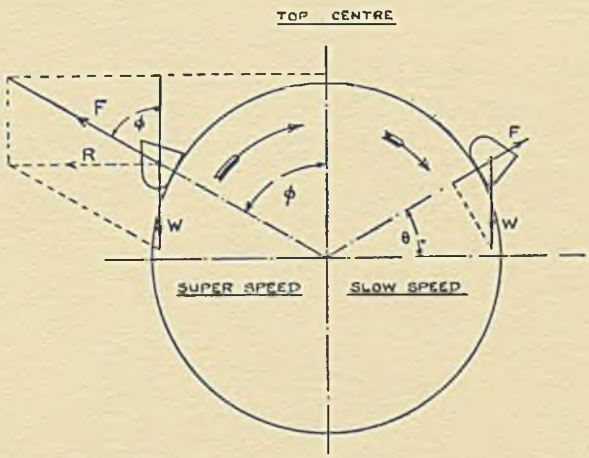


FIG. 85.—Position of Bucket Discharge.

In like manner the position of discharge corresponding to any other relation of F to W may be determined. It is clear that too high a speed for a given size of head wheel means premature discharge, much spill and loss of efficiency.

Inclined bucket elevators, whether belt or chain type, are run at a slower speed than vertical elevators. If inclined at not more than 70 degrees to the horizontal, both pick-up and discharge are decidedly better than in a vertical elevator run at the same speed. The discharge chute can be placed in a more favourable position to catch the load with a minimum of spill.

The spacing of buckets is important, and is governed partly by the size of the top wheel. If of large diameter, the spacing must be wide to avoid interference from the preceding bucket. If relatively small in diameter the radial force is greater for the same lineal speed, and therefore the " throw " is better. Also, for the same lineal spacing of buckets the angular spacing is greater in the case of a small wheel, and consequently the leading bucket is less liable to get in the way of the discharge from the following bucket and cause dispersion and spill.

But the cutting down of the top wheel must not be overdone, as very small wheels are not durable. In chain elevators the size is partly governed by the pitch of the chain and the minimum requirements as regards number of teeth in the wheel.

CHAPTER XI

VERTICAL AND INCLINED ELEVATORS (CLASS B)

1. **Vertical Elevators with Spaced Buckets.**—In vertical belt elevators, as used so extensively for grain, the pressed-steel buckets are fastened to a lap-jointed belt by a row of fang-headed bolts, which are prone to pull through the belt in course of time. The casing, whether made of wood or of

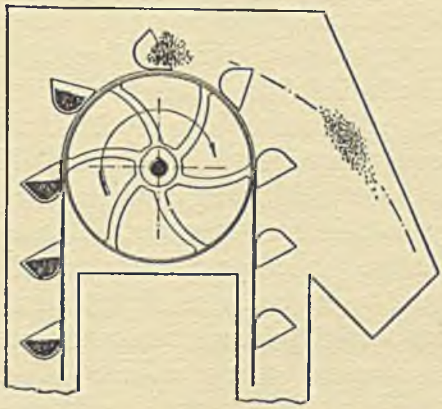


FIG. 86.—Head of Vertical Belt Elevator.

steel plate, is commonly divided into two legs (an up-leg and a down-leg), a form of construction seldom adopted in the case of chain elevators.

In Fig. 86 the bucket on the top centre is just in the act of discharging its contents, the speed being such that the "fly-away" radial force is equal to the intensity of gravity, or F equals W, giving a good centrifugal discharge and minimum spill.

In such an elevator the line joining the shaft centre to the edge of the discharge chute may be inclined at 20 to 30 degrees to the horizontal. The angle may be as much as 60 degrees, however, in the case of a slow-speed elevator for minerals, to get the chute low enough to receive the bucket discharge.

Whilst there are belt conveyors working of 1500 feet centres, most belt elevators are quite short in comparison. Still the respectable length between centres of 196 feet may be instanced in the case of an American vertical grain elevator having a 40-inch belt travelling at the high speed of 640 feet per minute over a 90-inch head pulley making 27·1 revolutions per minute. This elevator has a foot pulley of the relatively small diameter of 30 inches and a gravity tension gear to the bottom shaft. It is fed by a belt conveyor. The discharge angle is 25 degrees below the top centre to edge of chute.

An interesting example of a high-speed vertical belt elevator for handling small dry ore up to 2-inch size may be cited from American practice. The centres are 60 feet, the head pulley 60 inches diameter on a 7-inch shaft making 32 revolutions per minute, giving a speed of 510 feet per minute to a 12-ply belt 36 inches wide. This carries two rows of buckets, 17½ inches long by 10-inch projection, set side by side, and spaced 18 inches apart. The capacity of each bucket is 0·537 cubic feet, and the weight 36 pounds. The foot pulley is 48 inches diameter. This elevator is driven by a 50 H.P. motor. The actual daily capacity is 6000 short tons of ore, equal to an average of 250 tons an hour. The nominal full-load capacity is six times the working capacity, if the elevator worked every minute of the twenty-four hours; so there is a big margin for irregular feeding and stoppages.

The next diagram (Fig. 87) indicates the head of a vertical chain elevator running at a fairly high speed and giving a clean centrifugal discharge. In such an elevator the top wheel is commonly smaller in diameter than the head pulley of a belt elevator. This chain wheel may either have teeth or be toothless. A plain traction wheel runs more quietly than a sprocket wheel, and the frictional grip is sufficient to prevent slipping in normal working. The bottom chain wheel may also be toothless; but then there is the danger that the bottom shaft will cease to rotate in its bearings whenever the chain is allowed to get too slack.

The buckets, of **A** type, may be made either of pressed steel or of malleable cast iron. The latter buckets are the stouter and the more durable, especially for cutting or for damp materials, as malleable iron does not readily corrode, whilst mild steel does. Either metal may be galvanised.

The various sizes of Ewart or pinless chain, with K1 bucket attachments, are suitable for light or moderate duty, while the Gray and Ley pin chains are excellent for heavier work. The shorter the pitch of the chain the higher the speed at which it may be wisely run, with due regard to durability. Either bolts or rivets may be used to secure the buckets to the chain, but most commonly bolts are preferred.

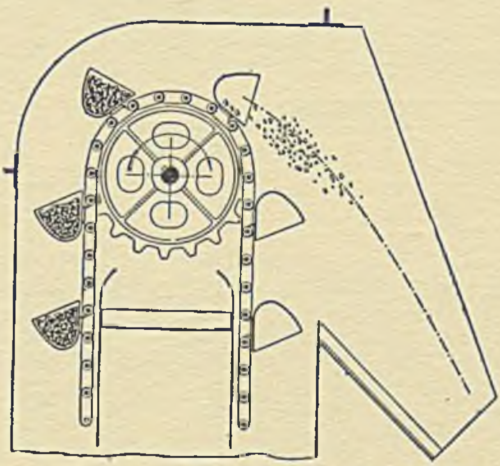


FIG. 87.—Head of Vertical Chain Elevator.

The bucket discharge takes place a little beyond the top centre, the parabolic trajectory being indicated. When the speed is too slow for a given top wheel the radial force F is weak and the trajectory too steep to prevent considerable spill down the casing and loss of efficiency.

Ideally one should be able to adjust the speed of an elevator to a nicety to suit various conditions by introducing a variable-speed gear in the drive, such as a pair of Reeve's expanding and contracting speed cones with friction drive or a P.I.V. gear with positive drive. This is hardly ever done, however; low first cost being so often the overruling consideration.

The drawing (Fig. 88) shows the upper and lower terminals of a substantial vertical elevator of 63 feet centres, designed for an average capacity of 60 tons of small limestone per hour.

The 18-inch buckets are made of special shape, to keep back their contents until the position is favourable for a clean gravity discharge at the slow speed of 100 feet per minute.

The buckets are not spaced wide apart but are bolted continuously to the K2 attachment lugs of a heavy Ley chain

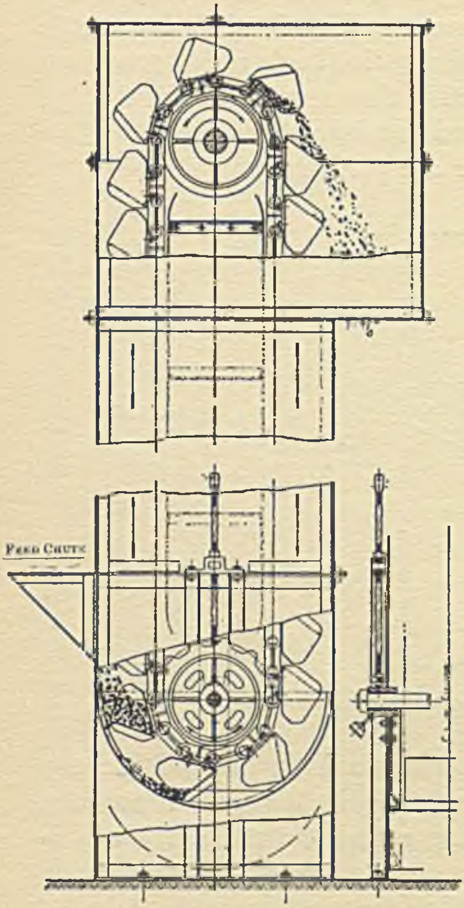


Fig. 88.—Slow-speed Limestone Elevator.

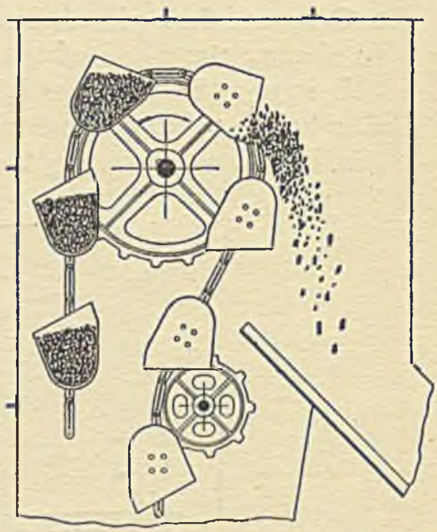
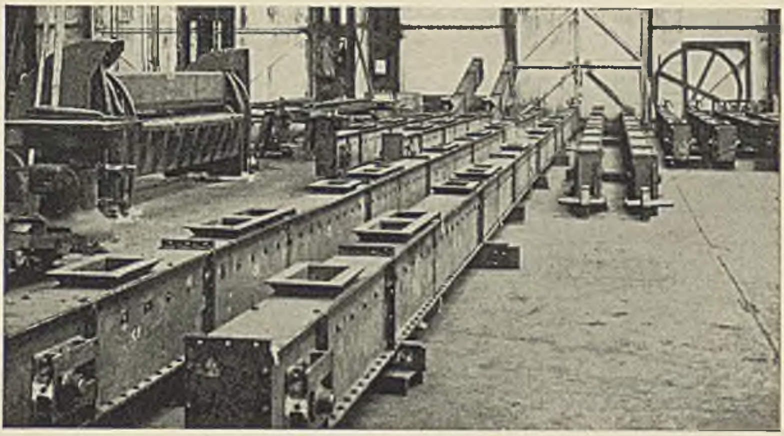
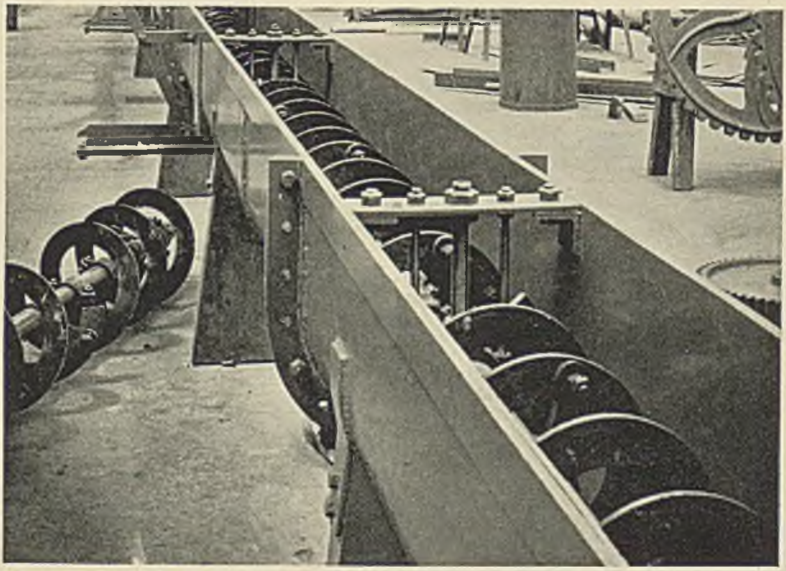


Fig. 89.—Head of Slow-speed Dump Elevator.

(No. 7140) of 6 inches pitch, fitted with forged manganese steel pins and renewable bushes. The top wheel is toothless (by request of the purchaser's engineer), but the bottom wheel has teeth. Also the top shaft is extra large in order to facilitate the interchangeability of certain details throughout an installation of ten elevators of different lengths and capacities in a cement works in India.



Group of Drag-link Conveyors.



Spiral or Worm Conveyor.

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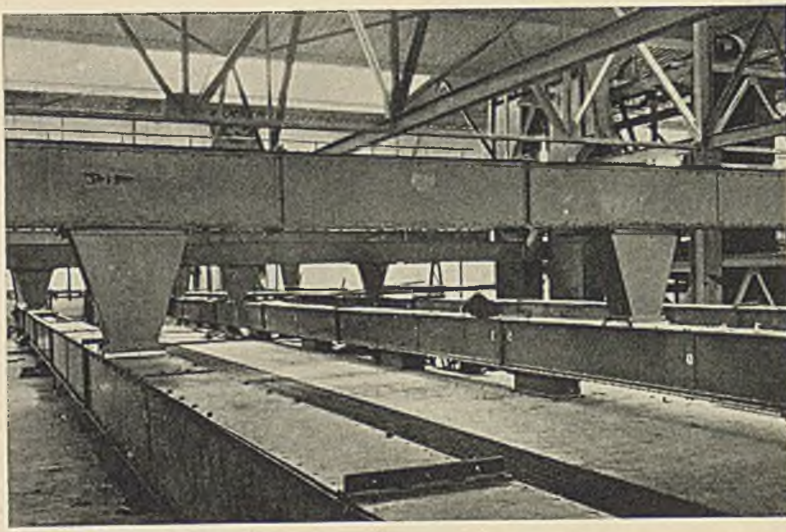
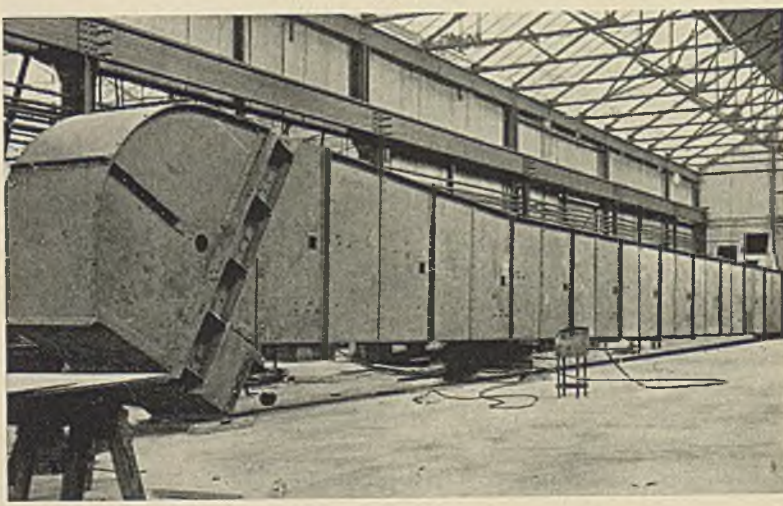


DRAG-LINK CONVEYORS FOR CATTLE FOODS.



LARGE ELEVATOR CASING IN ERECTING SHOP.

To face page 113.]

An interesting feature of this elevator is that the boot is designed to give a constant lip-clearance to the buckets, by causing the inner shoe to move up and down along with the bottom shaft as the adjusting screws are operated. The details of this design are clearly shown in the drawing. This movable shoe is an alternative to the method of preserving a constant bucket clearance by running the bottom shaft in fixed bearings and the top shaft in sliding bearings with screw adjustment, which somewhat complicates the driving gear.

2. **Double-strand Vertical Dump Elevator.**—The diagram (Fig. 89) shows how it is possible to overcome the bad delivery at slow speeds of an ordinary vertical elevator by deflecting the chains on the return strand so as to enable the discharge chute to be fixed vertically below the buckets at the point of discharge.

Top wheels of relatively large diameter and two strands of chain are essential, also two deflecting wheels and a wide casing, all of which mean additional cost as compared with a single-strand vertical elevator run at a high speed, but the advantages gained are worth the extra cost in many cases.

A good example of a dump elevator is given in Fig. 90. Its hourly capacity is 80 tons of fine cement at a speed of 100 feet per minute. The centres are 51 feet and the buckets 21 inches long, set 24 inches apart on a heavy Ley chain of 6 inches pitch (No. 7140). The head wheels are 35 inches diameter and of 5½-inch bore. The chain tension adjustment is at the top and the drive is through a belt and machine-cut steel spur wheels. The buckets are bolted to flat steel cross-bars, 6 inches wide, which in turn are bolted or riveted to the A-type attachments of the chains.

Experience proves, however, that this method of con necting the two chains together is too rigid and that in consequence cracks are liable to develop in the attachment links. The remedy is to fit swivel attachments (Fig. 41) which permit freedom of adjustment between the chains in the event of the two strands being not quite correctly matched.

In a recent noteworthy group of four dump elevators, of 98 feet centres, each elevator handles 60 tons per hour of white granulated sugar; the welded steel 18-inch galvanised buckets being carried at $31\frac{1}{2}$ inches pitch, through swivel attachments, by two strands of Ley's No. 330 malleable iron chain, fitted with special nutted pins, running at a speed of 150 feet per minute. These chains are protected by being sherardised throughout.

As it is not feasible to hot galvanise the $\frac{3}{16}$-inch flanged casing plates, they are internally sprayed with molten zinc from a "pistol"; a modern method of protection against

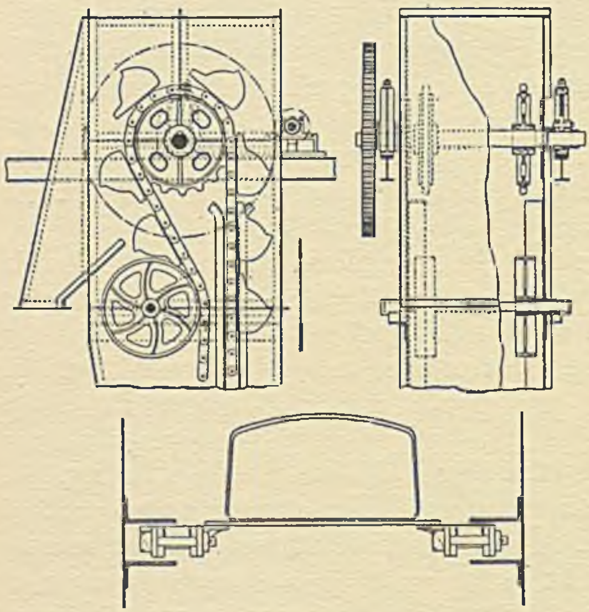


FIG. 90.—Head of Dump Elevator for Cement.

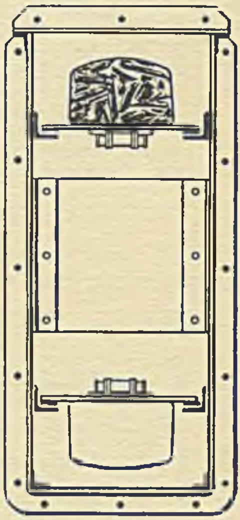


FIG. 91.—Cross-section of Cased Elevator.

corrosion that avoids distortion. The heavy guide angles and the steel-plate boots are similarly treated. This is a case in which paint as a protection against corrosion is clearly both inadmissible and inadequate. The top shafts of these elevators run in 5-inch roller bearings.

3. **Inclined Elevators with Spaced Buckets.**—The diagram (Fig. 92) indicates the ease with which a clean gravity discharge can be obtained from an elevator inclined at 60 to 70 degrees to the horizontal at a relatively low speed by arranging the discharge chute vertically under and well below the discharge point.

Some advantages of the inclined elevator as compared with the vertical are :—

(*a*) The pick-up in the boot is improved, the buckets filling better.
(*b*) There is more latitude of choice in the position of the boot.
(*c*) The discharge is better and the chute can often be much shorter.

Fig. 92.—Diagram showing Clean Discharge of Inclined Elevator.

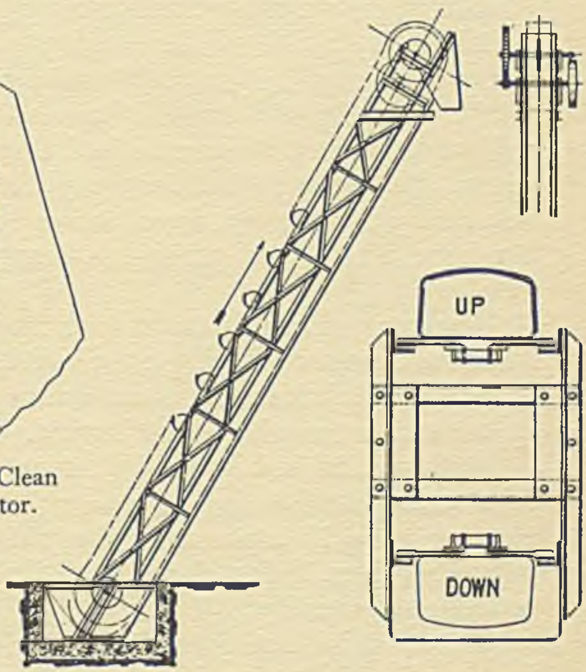


Fig. 93.—Typical Spaced Bucket Elevator.

The range of speed is from $1\frac{1}{2}$ to 3 feet per second, a very common speed being 2 feet per second, or 120 feet per minute, for a fair-sized elevator having buckets round about 18 inches long on a chain of 6 inches pitch. Small elevators have chains of shorter pitch and can well run faster.

Durability dictates relatively low speeds and large buckets, whilst low first cost demands higher speeds and smaller buckets.

The top or head wheel should not have fewer than 10 teeth, or 19·7 inches pitch-diameter for a 6-inch pitch chain ;

but a wheel of 14 teeth and 27·4 inches diameter makes a better job. Head wheels of 20 teeth and 38·7 inches pitch-diameter, though not unknown, are rare, because very big wheels have certain practical drawbacks. They necessitate top shafts of large diameter, heavier reduction gearing and more bulky casings, thus involving relatively high first cost.

Buckets of standard type must be spaced well apart to avoid "interference" and a scattering discharge into the chute. The bucket interval commonly ranges from 15 to 30 inches, according to the size of bucket and pitch of chain.

Skidders bolted to the buckets usually slide on guide angles protected by renewable steel wearing strips, secured to the angles by countersunk head-bolts. Hardwood wearing strips have been used to a limited extent to deaden the noise. As an alternative to skidders, supporting rollers or sprocket idlers may be adopted, keyed on to shafts revolving in fixed bearings, which are perhaps easier to lubricate than the long guides.

Another method is to fit each bucket with rollers about 6 inches diameter running on a crossbar having turned ends. It facilitates lubrication if these rollers are bushed with oilless carbonated or graphite-lined bushes.

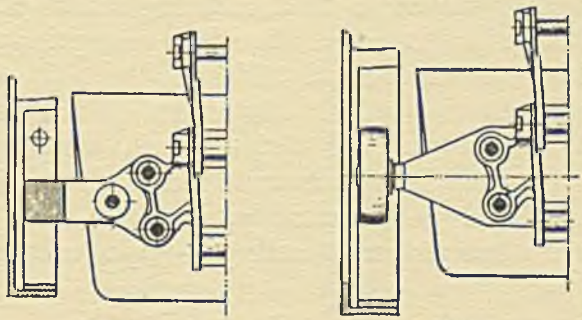
Both vertical and inclined elevators are preferably enclosed in a steel-plate housing or casing; not only to protect the running gear if exposed to the weather, but also to prevent dust from flying about, and for the sake of safety and orderliness generally.

A typical inclined spaced bucket elevator of simple design is shown in Fig. 93, in elevation and cross-section, with open-lattice steel framing, steel-plate boot sunk in a pit, and pressed steel dust-trough to catch any spill from the buckets; though a complete casing is far more effective in this respect, as indicated in Fig. 91.

As regards the driving gearing, it is sometimes more convenient to carry a countershaft on the frame some considerable distance below the head of the elevator, and to connect this intermediate shaft to the top shaft by means of a chain drive, instead of by spur gearing.

Inclined coal elevators, as used in gasworks, are commonly fitted with malleable iron buckets of the B type, with thickened lips, which are very durable, and give excellent service. The 24-inch bucket is the largest standard size bucket made and stocked, giving a capacity of 120 tons of coal an hour at 2-feet pitch. The 15- and 18-inch buckets are much oftener required, however, as a capacity exceeding 60 tons of coal an hour is seldom called for in a gasworks elevator serving a retort house.

Bucket Skidders and Rollers.—There are various ways of supporting the buckets of an inclined elevator, but the most common method is by means of skidder bars bolted to the back of the buckets and sliding on angle guides (Fig. 94). The skidders may be flat steel bars, or steel castings or chilled iron. These chilled iron skidders are cast thicker on the wearing part, and being much harder than mild steel skidder



(A) (B)

FIG. 94.—Bucket Fitted with Skidders (A) and with Rollers (B).

bars are far more durable. Yet they have the drawback of being rather brittle, which sometimes results in the skidders breaking instead of wearing out, especially if by reason of any accident the chain should break and fall down in a heap. Otherwise the chilled iron runners answer the requirements admirably and are made in several sizes to suit all standard buckets, the bolt holes being cast in. In use the wearing surface in contact with the upper and lower guides become smooth and polished, sliding with but little friction; especially in coal elevators where the dust acts as a lubricant.

Large inclined elevators may with advantage have rollers about 6 inches diameter fitted to the buckets instead of skidders; thus making each bucket into a carriage mounted on wheels instead of a sledge (Fig. 94). Though the first cost is thereby increased, the resistance to motion is reduced somewhat. The question of how best to lubricate the rollers then arises.

Another method of supporting buckets is to provide flanged supporting rollers, say, 9 inches diameter, at intervals of 3 feet or more below the lifting chain. Such rollers may either be keyed on to shafts 1½ inches diameter, running in fixed bearings, or they may have special long bosses revolving on fixed shafts. Sometimes ball-bearings are fitted to the rollers, and the shafts drilled up for grease-gun lubrication. The return strand of chain is often unsupported, hanging freely in an approximate catenary curve.

It is not often that a curved elevator is required, although quite successful curved elevators have been made for gas-works. One of the conditions of success is a curve of large radius; another is that sliding skidders must be avoided and either travelling rollers or fixed relieving rollers fitted at the bend. Otherwise there is excessive absorption of power and rapid wear on the curved guides.

A double-strand cranked elevator can often be substituted for a single-strand curved elevator with advantage, where the limitations of the site and awkward obstructions make a straight inclined path impossible.

Elevator Frames and Casings.—Open elevator frames

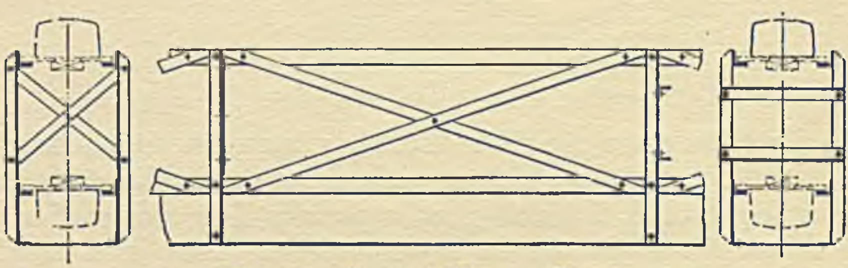


Fig. 95.—Typical Elevator Frame.

are of simple construction, being usually built up of angle-irons forming the guides, with angle-iron struts at intervals and flat-iron diagonal bracing; thus forming a series of panels about 6 feet long, as shown in Fig. 95. The longitudinal angles vary in strength according to the capacity and length of the elevator, but generally range from 2 by 2 by ⅜ inches to 3½ by 3½ by ½ inches. They are fitted with renewable wearing strips, commonly ⅜ inch thick, secured to the guide angles by countersunk head bolts at interval of about 18 inches. The skidders slide on those wearing strips, which in course of time wear very thin, and they can be renewed without detriment to the main angles forming the frame. The longitudinal guide angles are tied together transversely by cross angles, which fix the gauge or distance apart of the guide angles. In addition to these, resistance to racking forces is given by cross bracing at every other panel.[1] Below the guide angles a thin dust trough is usually fixed, with the object of catching any spill from the buckets. In spite of this provision, however, an open lattice-framed elevator is liable to be a somewhat dusty contrivance, especially in a situation exposed to high winds, and when the buckets are overloaded there is inevitably a certain amount of spill from the ascending buckets when nearing the top wheel. For this reason the fully cased elevator (Fig. 91) is preferred by many engineers; although a cased or housed elevator has the drawback of being more expensive in first cost than a lattice-framed elevator, and is also more troublesome from the point of view of accessibility to the buckets and chain. In some cases large manholes are provided in order to afford facility of access to the running gear. See Plate XII, page 113.

A commodious platform arranged round the head of an elevator is advantageous, with suitable access ladders. Some elevator users demand quite elaborate platform work, giving easy access to all bearings, while others are satisfied to do without any platforms. There is a happy medium in this matter as in most things. It is certainly better for the upkeep of an elevator to provide convenient platforms, in spite of their extra cost. Light open steel flooring is now much used.

Elevators are not limited in their application to the lifting of solid materials; both vertical and inclined elevators having been used for raising liquids and semi-liquids, such as sludge.

The Capacity of Elevators.—The lifting capacity or tonnage rate of an elevator is governed by at least six things, or is a function of six variables, viz. :—

(*a*) The size of the buckets, which varies in single-strand elevators from about 6 to 24 inches in length and from about 64 to 2200 cubic inches in capacity.

(*b*) The pitch of the buckets, which varies from about 1 to 3 feet.

[1] Constructional joints are either bolted or riveted or electrically welded, according to circumstances.

(*c*) The speed of the buckets, which varies from about 60 to 180 feet per minute or more. An inclined elevator can be run at a lower speed than a vertical elevator and still give a cleaner delivery; for the reason that in an inclined elevator the delivery chute can be placed vertically below the point of discharge.

(*d*) The rate of feeding, which should be as regular as possible. If the feed is irregular, some buckets will go up full, some half-full and others empty; thus the full capacity of the elevator is not obtained. When elevators are fed from coal breakers and stone crushers the rate of feeding is necessarily very irregular. This means that much larger buckets must be used than the average hourly capacity of the elevator would otherwise require. During short periods of rushes the momentary rate of working may be 100 tons per hour, while the average rate of working may not be more than 25 tons per hour. The buckets must, therefore, be large, otherwise the elevator will be flooded and spilling will occur.

(*e*) The density of the material, or number of pounds per cubic foot. The heavier the material the greater the hourly tonnage, other things being equal; but, of course, light materials, such as grain, are commonly lifted at a higher lineal speed than heavy materials, such as coal and ores.

(*f*) The size of the pieces of material. The smaller the pieces the better the material fills the buckets and the smaller the air spaces or gaps between the pieces. Large pieces of coal or stone do not pack well, and they require large buckets simply to accommodate them without jamming or danger of falling out, quite apart from the number of tons per hour to be lifted. The elementary fact is too often overlooked by inquirers.

In addition to these six well-defined factors, the lifting capacity of an elevator is also influenced by the shape of the buckets, the inclination of the elevator and the physical condition of the material as to wetness and viscosity. It is well known that damp fine coal is a troublesome material to lift, because it will not flow at all freely, but hangs up or bridges over, and stops feeding. Also damp coal dust clings to the buckets and forms an internal incrustation, which greatly reduces the effective capacity of the buckets. In like manner, sticky materials, such as moist sugar, wet lime, clay and mud, require buckets of special shape and cause trouble from hanging up and caking on. In fact, the buckets have to be cleaned out from time to time. There are many pitfalls that beset the conveyor engineer, owing to the variability of the physical properties of the various materials handled and the peculiarities of the conditions of operation.

When material is fed to an elevator from a large bottom hopper, some means of regulating the rate of feeding is convenient, if not necessary; such as a sliding door, a jigging feeder, or a rotary feeder. In cases where a few large pieces of coal are mixed with much small coal, a grid may be used to intercept the lumps instead of using a coal breaker. In gasworks, however, a coal breaker having either 2 or 4 rolls is generally used in connexion with coal elevators to reduce large lumps to a size of about 2-inch cube before carbonising.

It may be useful to introduce here in tabular form a rough suggestion as to the safe sizes of buckets and chains for various capacities of coal elevators inclined at 60 to 70 degrees and fitted with heavy malleable cast-iron buckets of standard type, as used in gasworks, collieries and power houses. Only the 24-inch buckets ever need two strands of chain.

TABLE X—ELEVATOR CAPACITIES

Tons of Coal per Hour.	Length of Buckets. B-Type.	Pitch of Buckets.	Suitable Ley Chain.	
			Long Elevator. Ref. No.	Short Elevator. Ref. No.
	Inches	Inches		
5	6	16	578	88
10	8	18	503	578
15	10	18	500	503
25	12	18	600	500
40	15	18	6140	600
60	18	24	7140	6140
90	21	24	7140	7140
120	24	24	2(1207)	2(1200)

4. **Double-strand Cranked Elevator.**—Cranked elevators are convenient for clearing obstacles and following the slope of roofs, instead of using curved elevators or inclined elevators with long delivery chutes. The details are generally similar to those of a vertical dump elevator, from which the cranked elevator has been developed. Some examples will be briefly referred to.

The drawing (Fig. 96) represents a cranked elevator at a

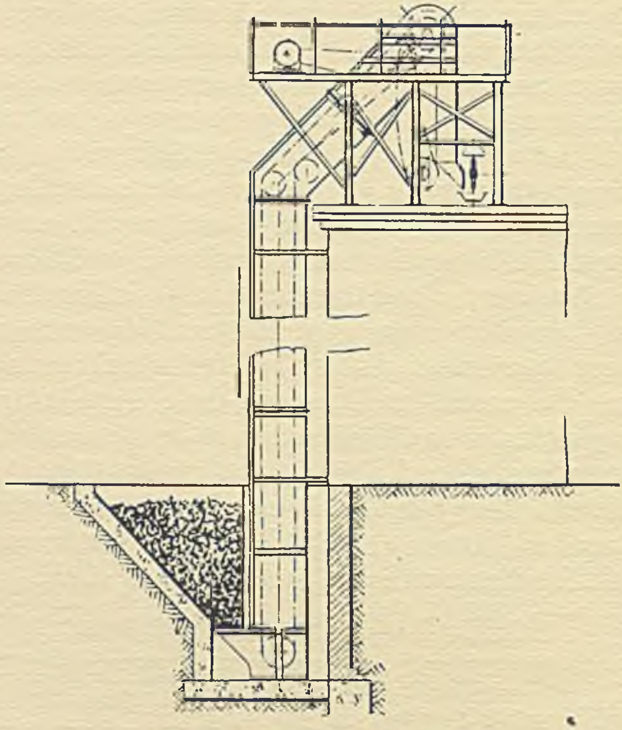


FIG. 96.—Cranked Elevator at a Colliery.

Yorkshire colliery designed to deliver 30 tons of small coal per hour into a simple scraper conveyor, discharging through several openings into a storage bunker.

Another example is remarkable for its great length, namely, 103 feet centres, having a long vertical leg and a short inclined leg, passing through the wall. It feeds 30 tons of coal per hour to a pulverised coal plant at the Derby Corporation boiler-house, supplying steam to the electric power station. This elevator is driven by a 15 H.P. motor. The 14-inch buckets are spaced 24 inches apart on two strands of Ley's No. 330 chain using G20 type attachments.

In a final example of such an elevator the inclined leg is arranged to lie just below the roof of an old retort house without occupying much headroom. This cranked elevator is of 58 feet centres and has 20-inch malleable iron buckets spaced 24 inches apart, the capacity being 40 tons of coal per hour.

It is driven by a high-speed compound engine of 40 H.P., which also drives a cross conveyor and a pair of shuttle-belt

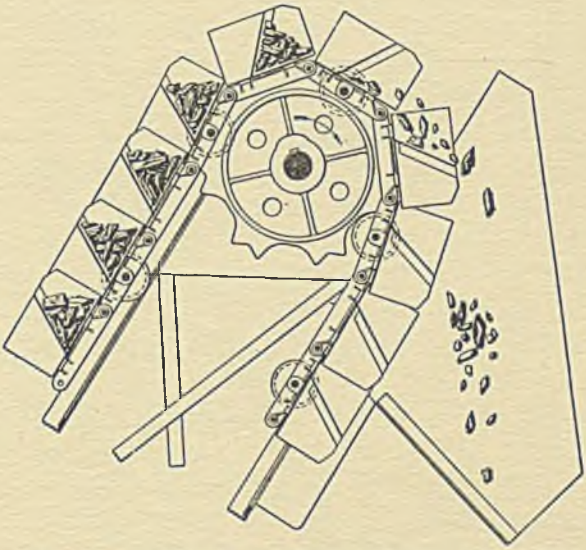


FIG. 97.—Head of Continuous Bucket Elevator.

conveyors travelling slowly to and fro over continuous coal storage hoppers serving the hydraulic retort-charging machine employed in this South London Gasworks. Still larger elevators of similar type have been erected at other gasworks, and have given complete satisfaction. See Plate XIII.

5. **Inclined Continuous-bucket Elevator.**—This type is specially suitable for many materials containing big lumps, and it is also much used for lifting smaller pieces of gritty materials like coke, stone and crushed ores. Such cutting materials are very destructive to dredging buckets. The principle is shown in the diagram (Fig. 97). The steel-plate buckets are so shaped as to form chutes at the discharge point; the contents of each bucket falling on the back of the

bucket in advance and sliding quietly off without much fall into the discharge chute. Thus the discharge is very easy at a slow speed of about 60 feet per minute, and there is a minimum of breakage. At the feed point the material is fed directly into the rising buckets from a chute and there is no

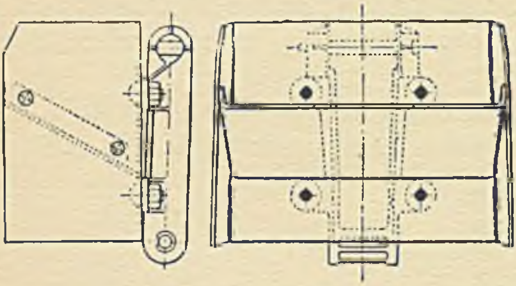


FIG. 98.—Continuous Bucket and Chain.

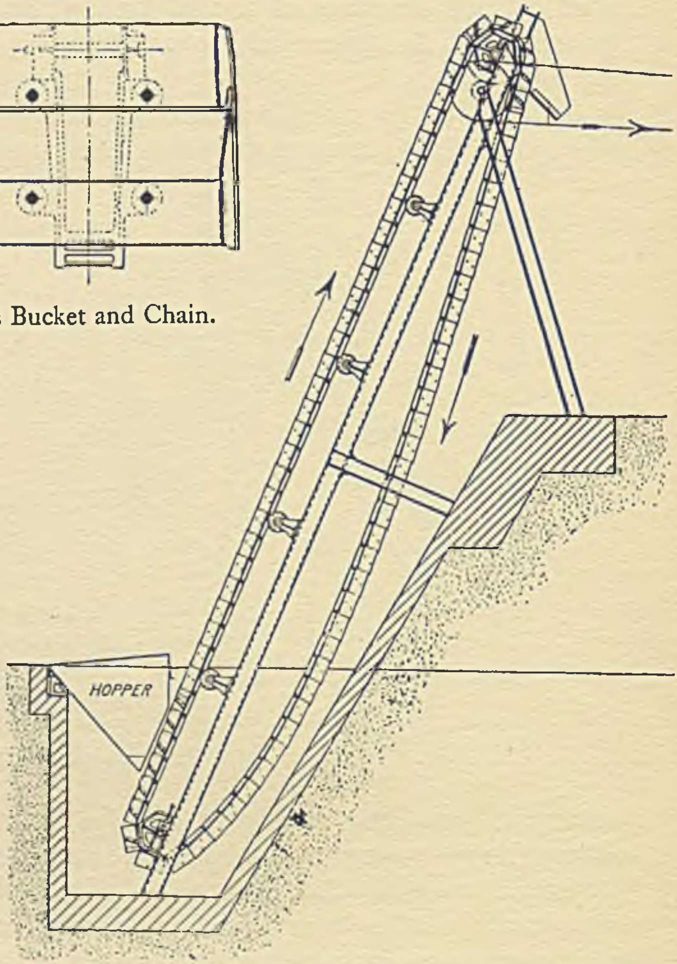


FIG. 99.—Simple Type of Overlapping Bucket Elevator.

dredging. This mode of feeding conduces to durability and also reduces the power needed to drive the elevator. Some very large and very long elevators of this type have been constructed.

Fig. 98 shows a common type of continuous overlapping bucket bolted to a Ley chain of 12-inch pitch; a steel plate being bent to form deep sides, and a crossplate either riveted or welded on obliquely to hold the load. The usual range of size is from 10 to 30 inches long. A reinforcing strip riveted or welded to the lip adds appreciably to the life of the bucket.

Buckets with a big overhang fitted to a chain of 6-inch pitch can be run faster than when fitted to a 12-in. pitch chain, and a smaller top wheel is then feasible.

A continuous bucket elevator of the simplest type is shown in Fig. 99 as often applied in quarries and gravel-screening plant. The rising chain runs on flanged supporting rollers, preferably chilled, the return strand hanging unsupported in an approximate catenary curve. Sometimes rough timbers are used instead of plain channel framing.

An alternative design of elevator has extra deep malleable iron buckets of special shape (E-type) with long angle backs, placed close together but not overlapping. This form is available in smaller sizes than the steel plate overlapping bucket variety; the malleable buckets being made in sizes ranging from 6½ to 15 inches long, and to suit chains of either 4 or 6 inches pitch. The chain speed may be 120 feet per minute. This design is very suitable for gravel elevators of small capacity.

There is a practical limit to the length of an elevator which is dictated by the strength of the standard chains available. When an extraordinary lift is called for, it is possible to divide up the duty between two or more elevators arranged in series, and thus reduce the load on the chain of each section to a feasible amount.

In this unique example (Fig. 100) for a lift of 150 feet two large elevators are arranged in tandem, the lower one feeding the upper one. Each elevator is of 80 feet centres and has 30-inch buckets bolted to two strands of No. 1207 Ley chain, giving a capacity of 150 tons an hour of crushed nitrate rock, known as caliche. The chain speed is 75 feet per minute, though the upper elevator runs slightly faster than the lower one, to prevent all possibility of a choke. Note the drive of both elevators from one motor. The feed is taken either from a large bottom hopper or from a tray conveyor at pleasure.

This chapter will be fitly concluded by reference to an elevator of quite exceptional size, having an hourly capacity of 500 tons of lumpy limestone up to 18-inch cubes. This big elevator, erected in North Derbyshire, is of 63 feet centres and has 54-inch riveted steel buckets $\frac{3}{8}$-inch thick, with extended overlapping sides. Mention has already been made of this elevator in Chapter VIII, where Fig. 55 is a detail drawing of the actual double-strand steel roller chain used; the chain is of 36-inch pitch and has $1\frac{3}{4}$-inch joint pins, also case-hardened steel bushes and rollers 5 inches diameter.

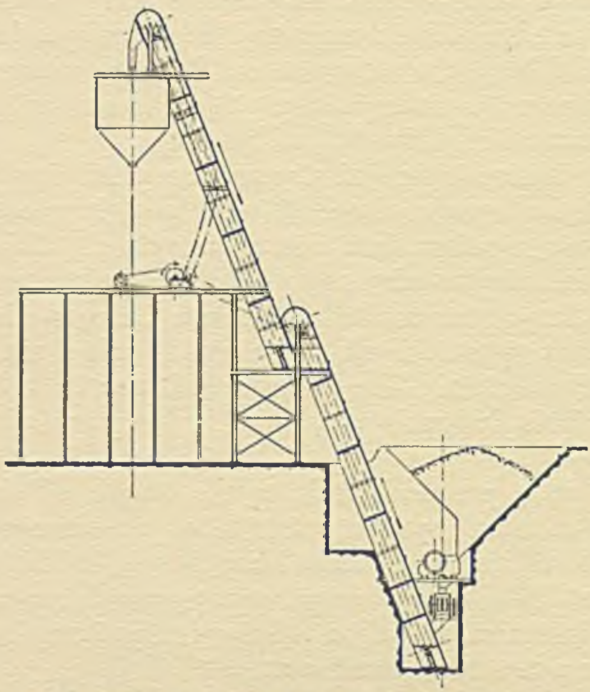


FIG. 100.—Pair of Caliche Elevators in Series.

The flanged supporting rollers, 12 inches diameter, run on heavy angle tracks forming part of the substantial lattice steel frame. The terminal sprocket wheels are 72 inches diameter, and the 9-inch top shaft runs in self-aligning split roller bearings. A view of this giant elevator in course of erection is shown in Plate XIV, facing page 129. There would be no technical difficulty in making an elevator of this type capable of raising 1000 tons of lumpy material per hour.

CHAPTER XII

ELEVATOR CONVEYORS

1. **V-bucket or Gravity-discharge Conveyors.**—The next class of machines to be considered are those designed for carrying bulk material in both a vertical and a horizontal path simultaneously, such as V-bucket conveyors and gravity-bucket conveyors. In the former the buckets are rigidly attached to a pair of chains, whereas in the latter and more popular type the buckets are pivoted to the chains and discharge their contents by tipping.

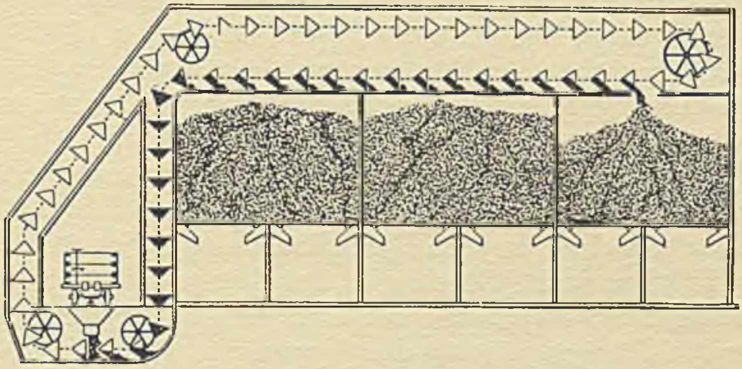


Fig. 101.—Diagram of V-bucket Conveyor.

In the V-bucket conveyor (diagrammed in Fig. 101) the buckets are of symmetrical shape and they serve as pushplates or flights on the horizontal run, just as in a scraper conveyor, a trough containing the usual discharge outlets being provided. This type is best suited to layouts where the vertical lift is high and the horizontal path is fairly short. Roller chains should be used to run freely on the horizontal tracks.

This is a good type of machine for handling coal or other non-abrasive material in large quantity, being simple in construction, not liable to derangement and of great carrying capacity. Obviously the transfer from the vertical lift to the conveyor trough is very gentle, the absence of the usual delivery chute at the top of an ordinary centrifugal discharge elevator enabling coal to be handled without breakage.

Along the horizontal run a V-bucket conveyor certainly absorbs slightly more power than does a tipping-bucket carrier of equal capacity and length. But, on the other hand, there are fewer wearing parts needing attention and lubrication; while the first cost is appreciably lower, partly due to the higher chain speed at which it is feasible to run.

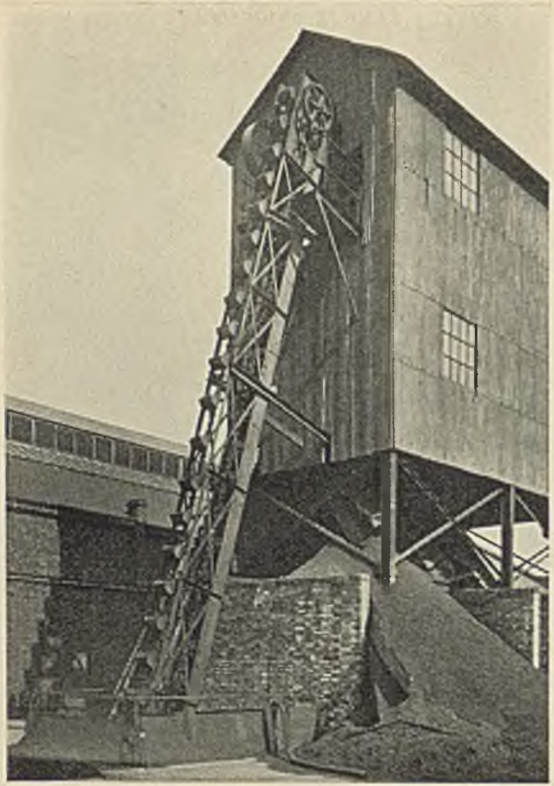
Some large V-bucket conveyors have been made by the Link-Belt Co. A conveyor having buckets 36 inches long by 20 inches wide, with a level capacity of 2·386 cubic feet will carry fully 200 tons of coal per hour when spaced at 18 inches and run at 100 feet per minute. This is at least double the speed at which it is wise to run a tipping-bucket carrier. At the same speed it is feasible to carry the big load of 300 tons of coal per hour, by using buckets of 4·395 cubic feet capacity, measuring 48 inches long by 24 inches wide by 11 inches deep, spaced 2 feet apart on chains of 24-inch pitch. Thus the V-bucket conveyor comes very much into the picture when loads of exceptional magnitude have to be considered.

An instructive application is presented by the coal-handling system of the Maryland Steel Co. at Sparrow's Point, which includes two elevators with V-buckets, 24 by 12 by 42 inches, spaced 3 feet apart, running at 105 feet per minute. The vertical lift is 94 feet, and the horizontal run 16 feet. The capacity is 110 tons (American) per hour of crushed coal. Each driving motor, of 40 H.P., has a very generous margin; the starting load being 27 H.P. and the running load 18 H.P., while the power needed to run the elevator empty is only 8 H.P.

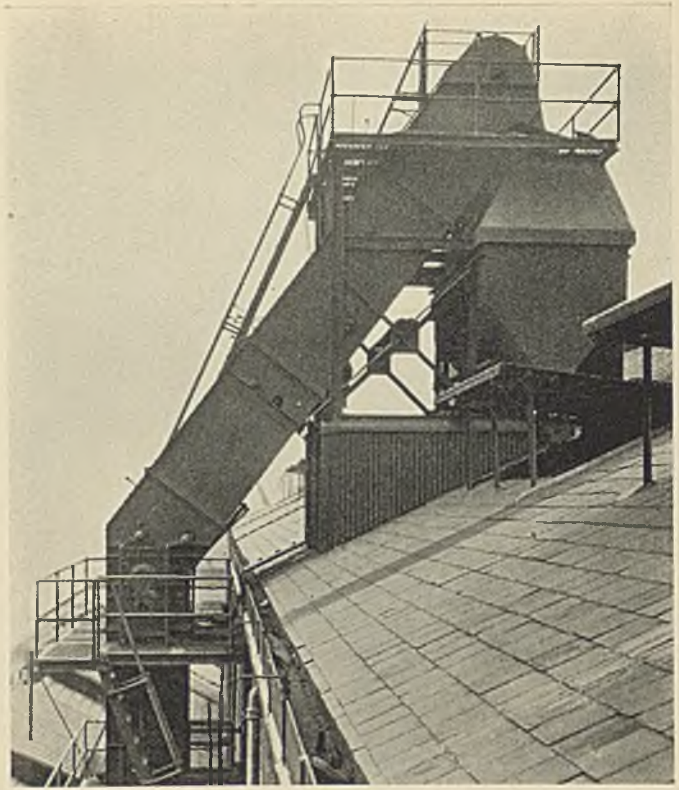
Both of these elevators feed a 30-inch belt conveyor of 253 feet centres, running over storage bins at a speed of 650 feet per minute, and equipped with a travelling tripper.

2. **Tipping-bucket or Gravity-bucket Carriers.**—A tipping-bucket conveyor consists of a pair of endless chains running over suitable driving and corner wheels, and carrying a series of buckets which are not rigidly fixed to the chains, but can swing freely on trunnions or pivot spindles. This form of conveyor does not differ greatly in principle from the

Plate XIII



Inclined Coke Elevator.



Cranked Coal Elevator.

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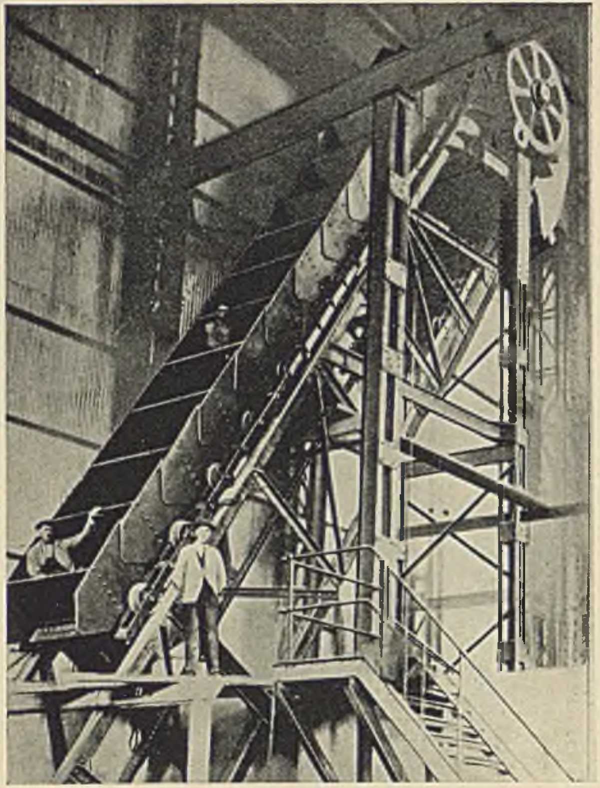
To face page 129.]



54-INCH CONTINUOUS BUCKET ELEVATOR FOR LARGE LIMESTONE.

18-INCH BUCKET ELEVATOR FEEDING FOUNDRY CUPOLA.

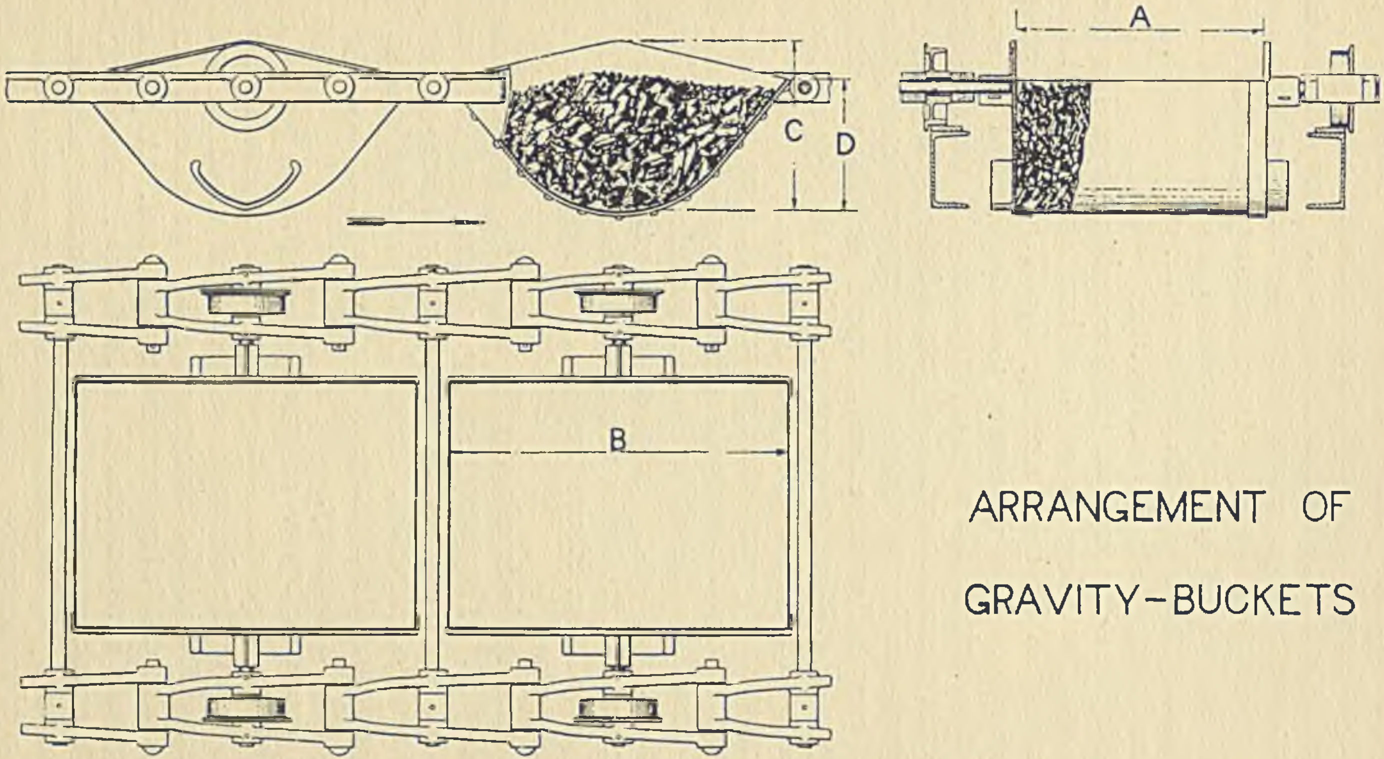


FIG. 102.—Section of Composite Gravity Buckets and M.I. Chains.

swing-tray type of package conveyor, and indeed it might with equal propriety be styled a swing-bucket conveyor. Its characteristic feature is that the centre of gravity of the full buckets must always remain below the axis of suspension; thus enabling the chains to travel horizontally, vertically, or indeed inclined at any angle without the buckets spilling. Each bucket is really a little tipping truck or car mounted on two small flanged wheels (see Fig. 102).

This form of combined elevator and conveyor has been much used for filling the overhead bunkers of power houses on account of its quiet running, durability and low power consumption. The customary slow chain speed of about 40 feet per minute has a good deal to do with the durability. No doubt the noise would be great and the upkeep heavy if the speed were increased to, say, 100 feet per minute; which is not regarded as an excessive speed for either a scraper conveyor or a V-bucket conveyor. Thus the tipping-bucket carrier is essentially a slow-speed machine.

In some early examples the same conveyor was utilised to carry ashes in the intervals when not required for carrying coal; but this double use is now obsolete. It had the objection that the life of an expensive conveyor was much shortened by the destructive action of the ashes on the buckets. Experience proved that it was far better to instal separate ash-handling plant.

Various methods of arranging and filling gravity buckets are adopted. They may overlap or there may be a small clearance space between them and the crossbars connecting the two strands of chain. In the former case the buckets can be filled from a fixed chute, whereas in the latter case a special rotary filler is necessary.

A common layout of gravity-bucket conveyor is that indicated in Fig. 103. The empty buckets run through a tunnel below the boiler-house floor, and could be utilised (if thought wise) for lifting ashes into an elevated bunker in the intervals when not in use for coal. A preferable arrangement is represented in Fig. 104, the latter needing less excavation, unless a tunnel is required for other purposes.

For emptying buckets a series of fixed trippers or dumpers are placed under the required points of discharge, one simple form of tripper being shown in Fig. 105. These trippers meet projecting cams on the ends of the buckets, which tip the latter through 90 degrees in order to discharge their contents, after which the buckets swing about for a few seconds before resuming the horizontal position. The speed of the

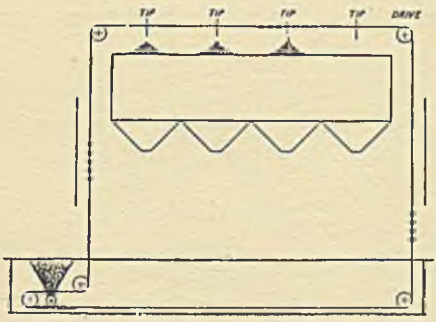


FIG. 103.—Layout of G.B. Conveyor.

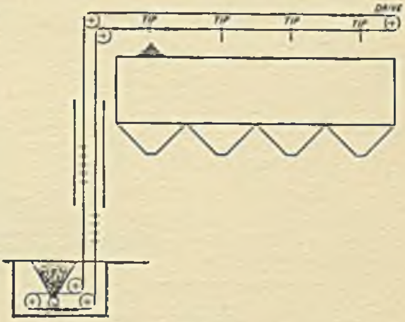


FIG. 104.—Alternative Run.

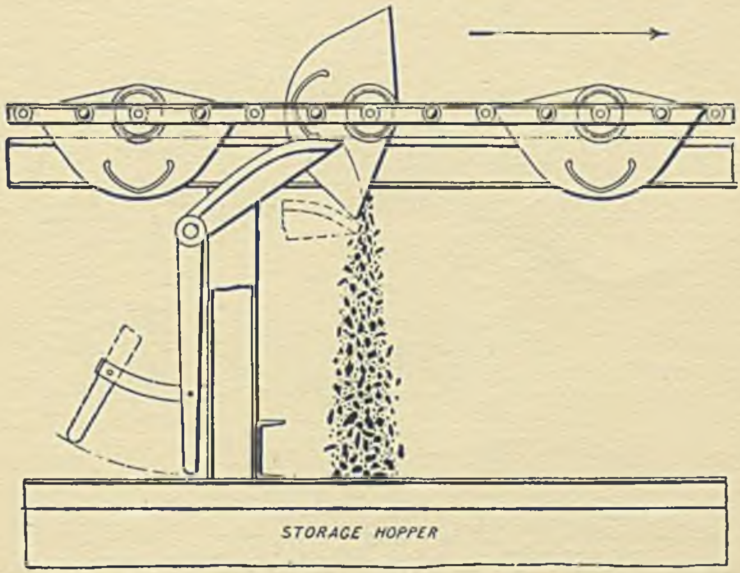


FIG. 105.—Detail of Bucket Tripper.

buckets should not exceed 50 feet per minute, while a slower speed is conducive to quiet running and durability.

For filling the buckets a rotary filler is placed between the feed hopper and the conveyor at the end of the lower run. This delivers a measured quantity of coal into each bucket, and prevents spilling between the buckets. One form of filler is shown in Fig. 106, this being driven by a chain from one of the corner shafts. Another form of filler is shown in Fig. 107, which is more effective for larger coal; and there are still other designs in use. Each may be driven by fixing a large sprocket wheel on the filler shaft and gearing the wheel into the main conveyor chain, or it may be driven by a separate chain from a corner shaft.

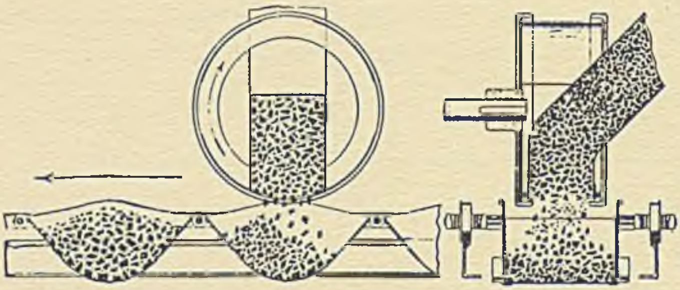


Fig. 106.—Drum-type of Rotary Filler.

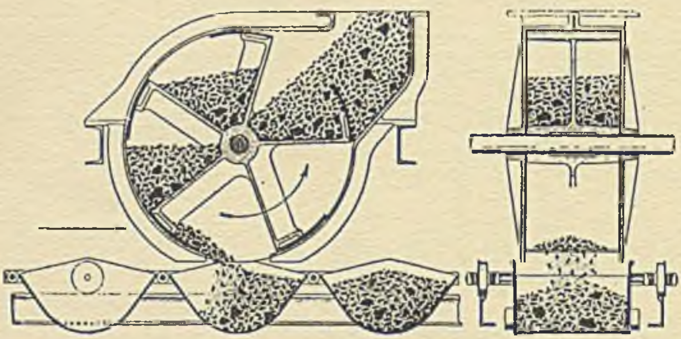


Fig. 107.—Fan-type of Rotary Filler.

Many buckets are made of pressed steel in one piece, with the cams of malleable iron riveted on; others are made in malleable iron, with the cams cast on. The particular detail shown in Fig. 102 is a composite bucket having malleable iron ends, with a steel-plate body riveted to the ends; this design having the practical convenience of enabling the same ends to be utilised for buckets of different widths by simply varying the widths of the body plates.

In this country most gravity bucket conveyors are fitted with flat link steel chains, but the No. 1412 malleable iron chain shown in Fig. 102 is also successfully employed, every link being alike and cast in one piece. The large bearing area of the pins is conducive to durability. The two strands of chain are connected by cross-stays between the buckets, which keep the gauge constant.

In America various types of tipping bucket conveyors with overlapping buckets are largely used. For handling lumpy materials these are better than the ordinary type with a gap between the buckets, because they can be fed at any point on the horizontal run by an ordinary chute or by a jigging feeder. For small coal, however, it is a debatable question whether the overlapping buckets are really worth the extra cost; the revolving filler being quite effective for feeding small material, and it is possible to employ travelling fillers when it is necessary to feed the conveyor at more than one point.

An unusual application of an overlapping bucket conveyor is depicted in Plate XV, this machine being designed to handle 25 tons per hour of Tate's cube sugar, weighing 48 pounds per cubic foot, from the ground floor to the storage hopper conveyors on an upper floor. The vertical lift is 63 feet, and the two horizontal runs total 88 feet, the upper run having three trippers. The 18-inch buckets are made of welded steel plates and are galvanised to protect the sugar from any possibility of soiling. The supporting rollers are lined with graphite bushes needing no oiling, nor is the chain lubricated in any way. The chain speed is 35 feet per minute. On account of the overlaps the empty buckets turn completely over at the end of the horizontal run. When descending they are neither horizontal nor inverted, but occupy an intermediate or vertical position.

3. **The Peck Carrier.**—In America great use has been made of a special overlapping bucket conveyor known as the Peck carrier, so styled from the name of its designer, Staunton B. Peck, Vice-President of the Link-Belt Co. Fig. 108 gives a detail of the chain and buckets.

The adoption of overlapping lips on the buckets to prevent spill without a revolving filler introduces a mechanical difficulty shown in Fig. 109. From the upper diagram (*a*) it is clear that on the lower run the rear of each bucket is overlapped by its follower. Hence, as a bucket starts to ascend, its rear lip cannot get free, with the result that the bucket spills its contents and no coal is raised.

One way of overcoming this difficulty is to apply a tilting gear (*b*), which tilts all the buckets before they enter the lower run and reverses the natural lap. Then the full buckets can rise freely with their load to the top run. This tilting gear, however, introduces extra wear and tear.

Another and better way (*c*) of freeing the overlapping buckets at the bottom of the vertical lift is to suspend the

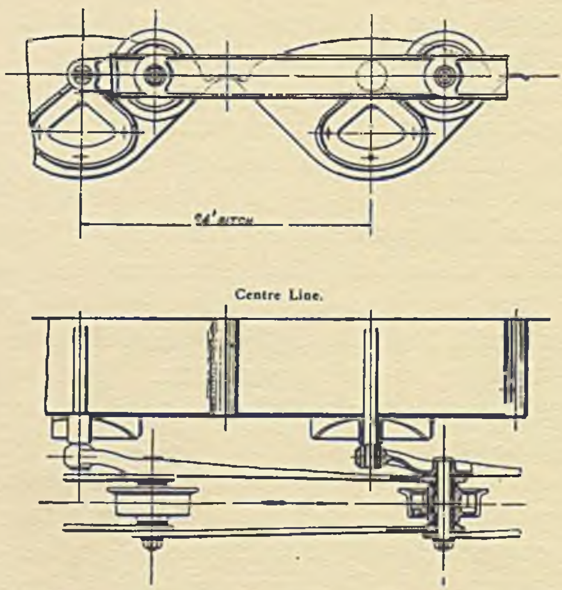


FIG. 108.—Detail of Bucket and Chain for Peck Carrier.

buckets from arms projecting 6 inches in the rear of the joint pins of the chains, and this alternative method is adopted in the Peck carrier. Then, in passing round the corner wheels, the buckets move in the arc of a circle of larger radius than the joint pins. Thus the buckets are automatically separated at the critical points, and it matters not which way the buckets overlap along the lower run.

The Peck carrier is the only overlapping conveyor in which throughout its entire path (whether vertical, horizontal, inclined, or curved) the buckets can always maintain their proper carrying position by gravity alone. It is the only form in which a fully loaded bucket can make a complete circuit without discharging its contents.

The buckets are malleable-iron castings in one piece. The overlapping lips are inverted V-shaped, so that they cannot carry material and spill at the turns. The chains are also malleable cast iron, because this material resists the

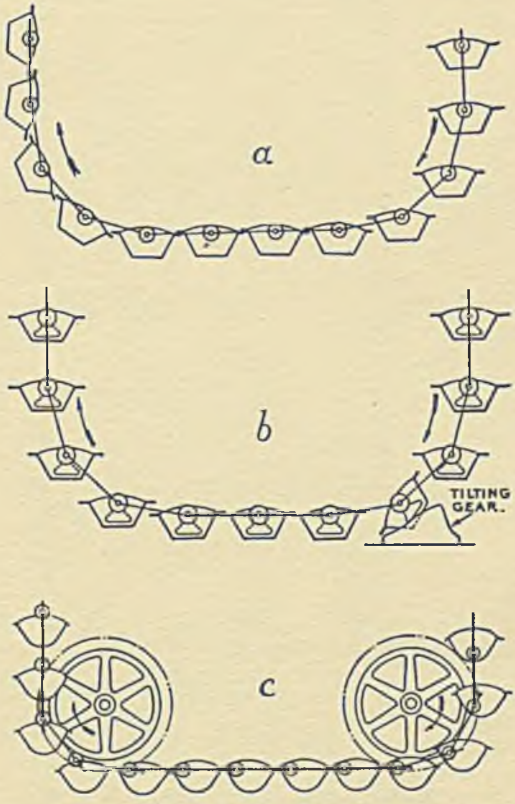


Fig. 109.—Diagram showing Bucket Interference.

corrosive action of wet coal and wet ashes better than steel, and because the wide seat for the ends of the bushings and pins cannot be obtained in a link of flat bar steel without useless weight in the body of the link, whereas the large bearing area can be very conveniently obtained in the cast links.

A movable discharger or dumper may be used, engaging the cams on the sides of the buckets and so tipping the contents. Alternatively, a fixed discharger is fitted at each of the required discharge points, as shown in the illustration (Fig. 110). This shows a Peck carrier used as an elevator only for raising the coal and ashes to overhead storage bins,

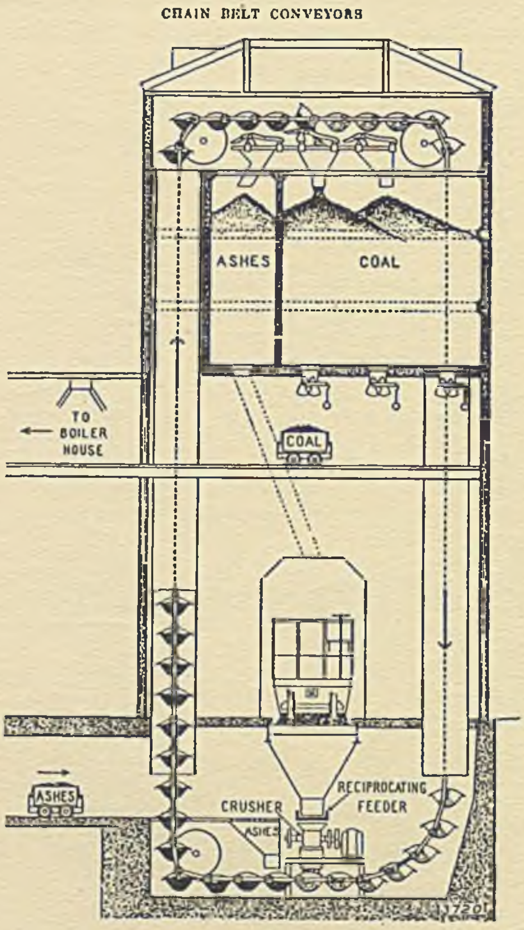


Fig. 110.—Peck Carrier in Boiler-house.

the distribution of coal within the boiler-house being effected by trucks, as also the removal of the ashes. It will be observed that this conveyor is fed from a large receiving hopper through a jigging feeder and a crusher to break up the large lumps of coal.

A jigging feeder consists of a reciprocating plate below the hopper actuated by eccentrics. Thus the rate of feeding can be controlled by the number of reciprocations per minute and by the length of stroke, both of which can be adjusted so as to give a fairly uniform rate. The rate of feeding is, therefore, independent of the opening in the hopper, if the latter is made of such size as to permit the free flow of the largest pieces of coal. The action of a reciprocating or jigging feeder is clearly represented in Fig. 111, the diagram A

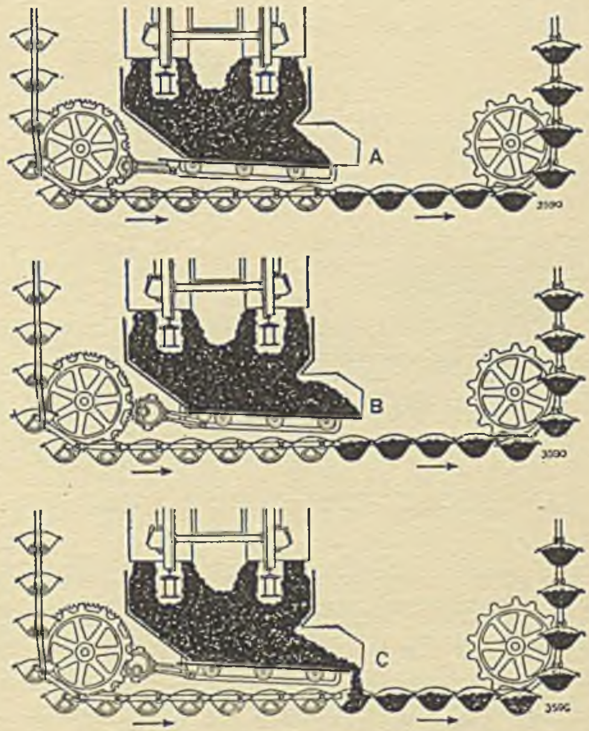


FIG. 111.—Reciprocating Feeder in Action.

showing the bottom plate at the beginning of the advance, diagram B at the end of the advance and diagram C the effect on the coal of the return stroke of the bottom plate. It is true that a conveyor with overlapping buckets can be fed from a simple chute ; but, of course, there is then danger of very irregular feeding, and occasional flooding of the buckets by sudden rushes of coal, which means spill.

An alternative method of feeding an overlapping bucket conveyor is given in Fig. 112. This shows an auxiliary slat conveyor or link-belt apron feeder with corrugated slats delivering coal from a bottom hopper below the railway track into a coal breaker, from which the coal falls into the lower run of buckets. Thus the entire contents of the wagon may be dumped at once into the receiving hopper, and delivered in a fairly steady stream into the main conveyor. The feeding belt is inclined, in order to economise height and reduce the depth of the conveyor tunnel or trench. The feeder can be driven by a variable speed motor, thus enabling the rate of feeding to be adjusted to a nicety.

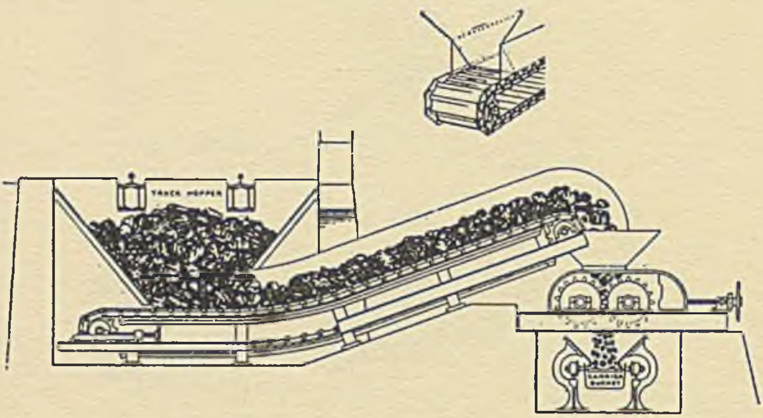


FIG. 112.—Apron Feeder in Action.

Although it is usual for conveyors to discharge at one point only at any one time, it is possible to make special gravity-bucket conveyors which are capable of discharging their contents simultaneously at two or three different points. Certain of the buckets are made to discharge at one point, while other buckets will pass this point and discharge at another point further on.

Peck carriers have been made in capacities ranging from 15 tons to about 150 tons an hour at the slow speed of 40 feet per minute. The three most common sizes may be rated at 20, 40 and 50 tons of coal per hour, the respective bucket dimensions being 18 by 15 inches, 24 by 18 inches and 24 by 24 inches. The width of the bucket is made equal to the pitch of the chain, which is either 18 or 24 inches.

CHAPTER XIII

THE DRIVING OF CONVEYORS AND ELEVATORS

ALTHOUGH conveyors have been kept especially in mind when writing this chapter, many of the remarks are almost equally applicable to some other branches of mechanical engineering, including crane work, crushers and printing machines.

In common with most classes of machines there is a remarkable variety of methods of driving continuous conveyors and elevators ; the modes of transmitting power from its source to the point of application of the load being both numerous and of much general interest.

The method of applying the torque direct to the main shaft by means of a pair of steam cylinders and cranks, so common in locomotive practice, is totally unknown in conveyor practice. Also it would be equally absurd to couple a large slow-running electric motor direct to the main shaft of a conveyor ; the cost alone of such a special motor being wholly prohibitive. Thus a train of reducing gearing of some kind is quite necessary, and the problem is to determine what form of reduction should be adopted, having regard to the various technical and commercial considerations involved.

Some of the points to be considered in arranging a **conveyor drive** are convenience, first cost, quickness of delivery, mechanical transmissive efficiency, durability, reliability or freedom from breakdowns, compactness, quietness in running, cleanliness, dust tightness and facility of lubrication. Of recent years multiple V-rope drives from electric motors have become extremely popular.

Fifty years ago high-pressure hydraulic engines were employed for driving a series of band conveyors in Liverpool grain warehouses ; but that particular application of water power has long been obsolete. Hydraulic engines are too wasteful for constant work. Hydraulic power is more suitable for heavy work of an intermittent character, such as the operation of dock gates and coal hoists raising full wagons of coal for shipment.

Thirty years ago small steam engines were in much favour for driving conveyors, and are still employed in some gasworks. But the most common source of power nowadays is a high-speed electric motor, this obviously requiring far more reducing gear than is necessary in the case of a steam-engine drive. An engine usually drives by a belt from a pulley on the crankshaft to a pulley on a countershaft, which latter is geared by a spur wheel and pinion to the main shaft of the conveyor or elevator. In some cases the steam engine will drive a main line-shaft through a belt or ropes, from which a second belt will transmit the power to the countershaft; other plant being also driven from the same line-shaft. A gas-engine drive is often arranged similarly, and the long flexible belt helps the flywheel to smooth out the explosive shocks and irregular turning moment or torque of the engine.

The same mode of driving through a line-shaft is sometimes adopted in the case of motor-driven plant; but of recent years it has become more customary to use individual motors, one for each conveyor or other machine. These individual motors commonly run at speeds varying from 750 to 1500 revolutions per minute, thus necessitating either treble-reduction spur gearing and two countershafts to get down to the slow speed of the conveyor main shaft, or else worm reducing gears (Fig. 113), either single or compound, and with or without oil-cooling devices. In some cases indeed a conveyor is required to run at such a very slow speed that treble-reduction worm gearing in series is necessary, as, for example, in continuous dryers and in continuous annealing furnaces. Alternatively there are available various types of special reducing gears of compact form and large reduction ratio which can sometimes be utilised to advantage, more especially on account of their compactness, neatness and convenience, seldom on the score of economy in first cost.

The driving gear of package conveyors of the double-service slat type is somewhat unusual, inasmuch as the main shaft of the conveyor is always vertical, whereas in most conveyors the driving shaft is horizontal. As a rule the main shaft of a double-service conveyor is driven through a worm-wheel reduction and belt from a motor below the conveyor,

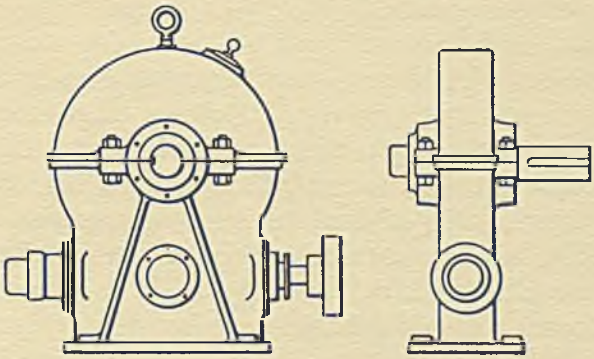


FIG. 113.—Worm Reduction Gear.

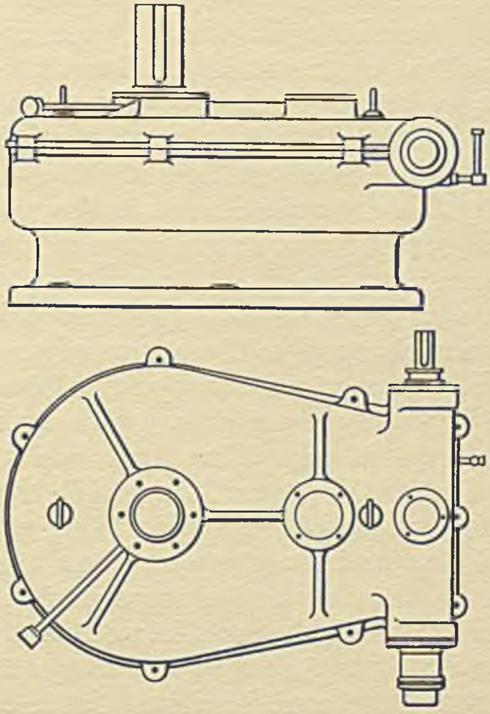


FIG. 114.—Combined Worm and Spur Reduction Gear.

as depicted in a former photograph (Plate II), an oil-drip tray being placed below the wheel. In other cases, however, bevel wheels are used.

Probably the best way of driving a double-service conveyor is to use a worm wheel enclosed in an oil-tight cast-iron casing forming an oil-bath; the worm being made of nickel steel, hardened and ground, and the worm wheel being provided with a gun-metal or phosphor-bronze rim, machine-cut or hobbed to fit the worm accurately. The only drawback is the high initial expense; but this is justifiable on account of the increased cleanliness, durability and freedom from heating of such a drive as compared with a rougher job. In order to increase the efficiency of the drive the shafts are fitted with ball-bearings and ball-thrust washers. Fig. 114 shows a combined worm and spur wheel reduction gear of the fully enclosed type.

Small self-contained electric motors from $\frac{1}{4}$ to 2 H.P. are obtainable with the double-reduction spur wheels contained in a cast-iron oil-tight housing, reducing the speed from 1500 revolutions per minute of the armature down to 150 or even 80 revolutions per minute of the slow-speed shaft. Such motors are extremely compact and convenient for light conveyor work, as well as economical. Ordinary single-geared electric motors of any required size are also made with the open back shaft running at any speed from 150 to 250 revolutions per minute.

In the case of coal-face conveyors for mines, electric motors are commonly used as the source of power for band conveyors and chain scraper conveyors, whereas coal conveyors of the jigging type are often driven by reciprocating compressed-air engines. In this application of conveyors, compactness of the driving gear is especially important, the height available for coal-face conveyors being very restricted.

In arranging an ordinary conveyor drive where a source of power already exists, such as a conveniently situated line-shaft, the choice of the most suitable method is usually confined to the comparative merits of a belt or a chain, though in the past ropes have sometimes been used to drive conveyors, and quite often spur gears and bevel gearing.

Here arises at once the question as to whether the particular conveyor is required to be started and stopped independently of the line shaft. If this is a necessity, then fast and loose pulleys and a suitable belt-moving gear must be provided on the countershaft of the conveyor when driving by means of a belt. Alternatively a friction clutch can be used, but this has the drawback of being more expensive.

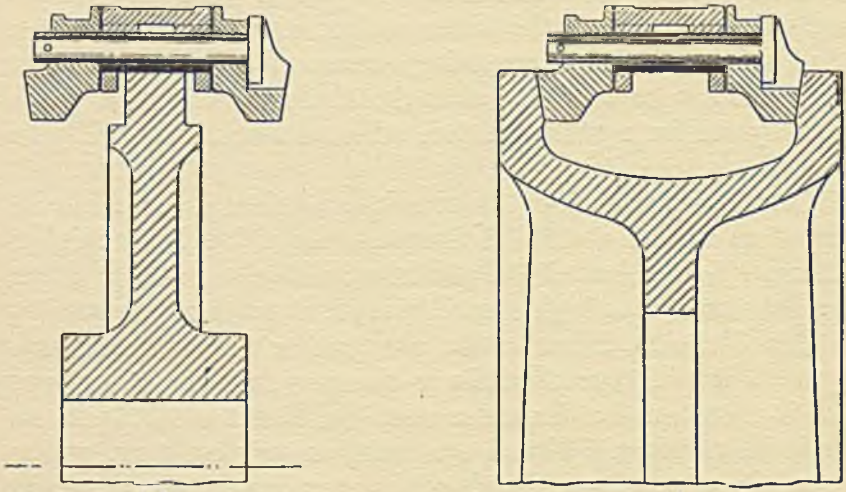
In the case of a **chain drive** there is no alternative but to provide a friction clutch when the conveyor is required to be started and stopped from time to time independently of the line shaft; although occasionally a clutch of the jaw type can be utilised when the speeds are slow, the jaw clutch being cheaper than a friction clutch.

There is one point in which a chain drive scores over a belt drive, and that is the possibility of connecting two shafts which are not quite parallel. In other words, not only are both quarter-twist and half-twist drives possible, but also **angle drives,** though the latter are not often required except when driving inclined revolving screens fed by an elevator. It should not be forgotten that the chain links require to be specially set for a twisted drive, whereas stock links will give trouble.

On the question of mechanical efficiency, or ratio of output to input, a well-lubricated chain drive has a higher efficiency than a belt drive, the friction on the bearings being certainly less. For high-speed drives it is necessary to employ machined chains, either of the pin type or the inverted tooth type. The pin type of chain is cheaper than the other type and is narrower for the same strength, but it is not quite so silent in running. There are many cases, however, where a well-lubricated machined chain running in a dust-tight oil-casing is not a feasible proposition, and the alternative is to use a chain that will run with little or no lubrication. The Ley bushed chain fitted with hardened steel renewable bushes is a type of drive that will give satisfaction in a dusty atmosphere, even where no lubrication whatever is possible, and the durability is increased by the use of manganese steel pins and bushes. This chain, however, is not suitable for high speeds, as it is not made with a shorter pitch than 3 inches, and, of course, only chains of short pitch can be used when high speeds of rotation are in question.

Another type of chain that is not so well known as it should be is the **grip chain,** which is designed to run on a small driving sprocket wheel, and to engage frictionally only with a large driven grooved wheel. Sometimes both the driver and the driven wheels are grooved, teeth being completely excluded. This grip chain is particularly well adapted to meet the condition of a rather large ratio of reduction at one step.

An interesting application of the frictional grip chain to the driving of a large elevator is shown in Fig. 115, where the driving sprocket wheel is of 12 inches diameter, having twelve teeth, and a 3-inch pitch chain transmits the motion to a grooved wheel, 60 inches diameter, keyed on the top shaft of the elevator, which in this case runs in roller bearings. Such a drive has been found to be very durable and to give no trouble whatever, even without any lubrication.



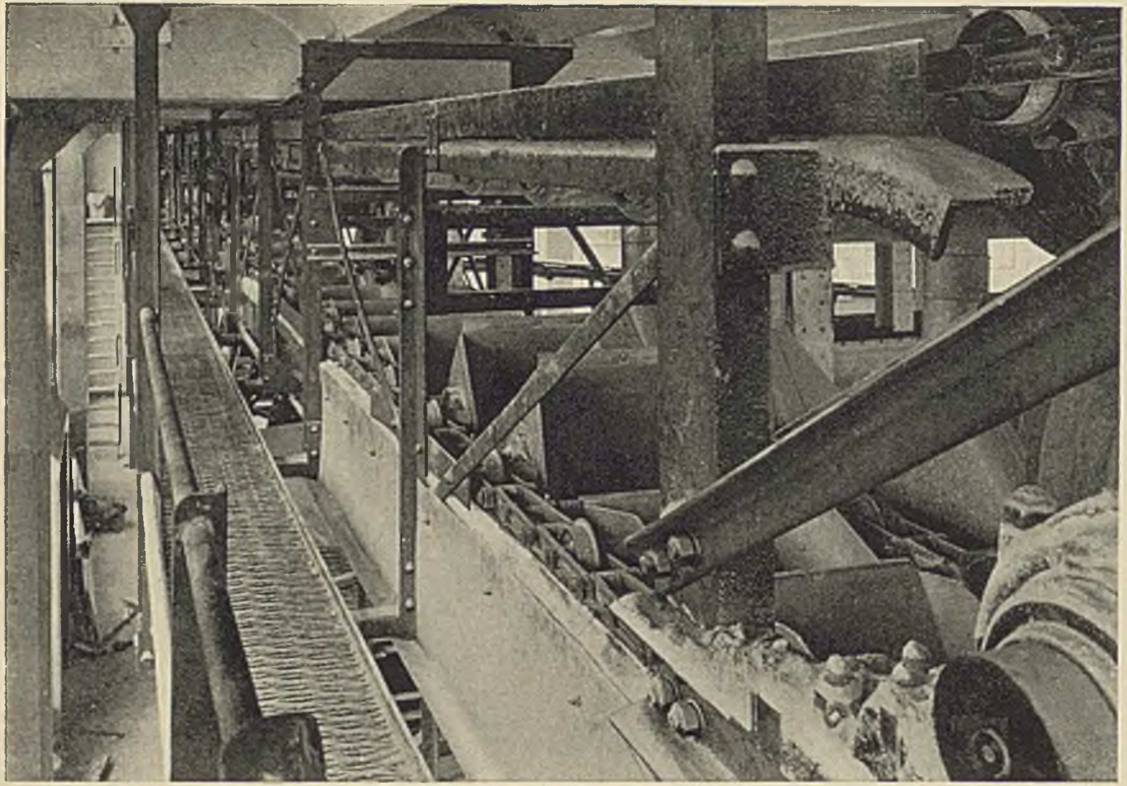
(*a*) (*b*)

FIG. 115.—(*a*) Toothed Driver. (*b*) Grooved Follower.

Sometimes a V-rope drive with grooved pulleys is preferable to the ordinary belt drive, especially when the shaft centres are unusually close together and the ratio of reduction is rather high. It does well, for example, on an air-compressor drive from a high-speed motor. The desirable property of flexibility is also more marked in the case of a V-rope than in a leather or balata belt. In this respect, as well as in silent running, a V-rope drive is better than a chain drive.

Electric power lends itself well to facility of control by means of switch gears and the adoption of safety appliances, including the automatic cut-out or overload release, though additional safety against overload can be secured by the use

Plate XV

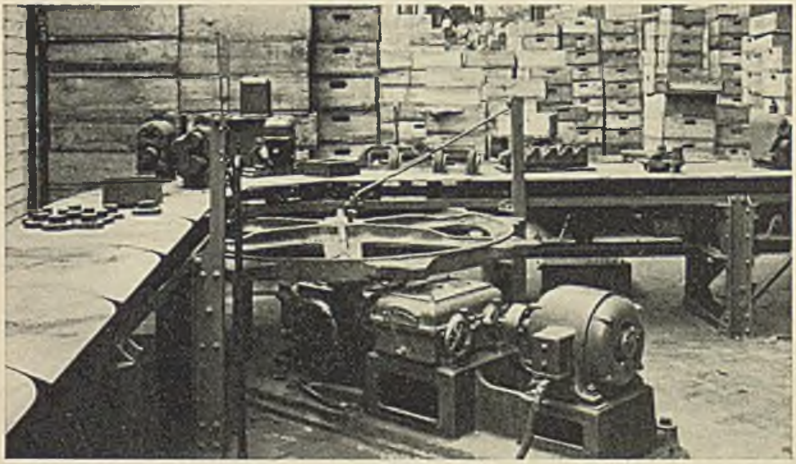


Top Run of Gravity Bucket Conveyor for Cube Sugar.

[To face page 144.

Plate XVI

General View of 24-inch Core Conveyor.



Driving Corner of above Core Conveyor.

To face page 145.]

of a wood or a copper key or by shear pins. In the case of continuous elevators serving a high warehouse, it is usual to have a push-button control, enabling the elevator to be started and stopped conveniently at each floor of the building. Alternatively a rope-operated switch can be installed at less cost.

The transmission of power by electric cables is economical, clean, noiseless and flexible. Another point in its favour is the ease with which the current transmitted can be measured by means of an ammeter, enabling the power to be deduced from the ammeter reading and the known voltage of the current, thus

$$\text{Electrical horse-power} = \frac{\text{volts} \times \text{amperes}}{746},$$

from which it is only necessary to divide by the efficiency of the motor to get the brake horse-power required to drive the conveyor.

A further advantage of a direct-current motor is the ease and simplicity with which the speed can be varied according to requirements throughout a wide range. Nowadays there is a marked tendency to equip conveyors with variable speed motors, enabling the speed to be adjusted to a nicety, neither too fast nor too slow for the particular duty.

Unfortunately, this facility of speed control is not an attribute of alternating current motors, whose speed cannot be conveniently varied except in large steps unless an expensive commutator-type motor be used. When driving a conveyor by means of a 3-phase motor it is generally more feasible to instal a mechanical variable-speed gear of the Reeves' type than to rely on switch mechanism. In this gear expanding and contracting cones are used, connected together by a short belt carrying wood gripping pieces. The standard sizes of this variable-speed gear range from about 3 H.P. to about 40 H.P. As a simple alternative stepped speed cones are occasionally used and an ordinary belt.

Another alternative is the so-called positive infinitely variable (P.I.V.) speed gear, using a special chain; but this gear is apt to become very noisy as it wears.

One of the best-known and most convenient devices for obtaining a very large reduction ratio in a small space is known as the H.R. gear, from the name of the inventor, E. C. Hatcher, and sometimes referred to as the *Hatcher gearbox*. It consists of a group of worms and wheels forming a compound train, all compactly enclosed in a cast-iron oil-tight casing; the first and final shafts being arranged coaxially, as a rule, though sometimes at right angles. The standard gear ratios range from a minimum of about 10 to 1 to a maximum of about 400 to 1; but much higher ratios are possible whenever required.

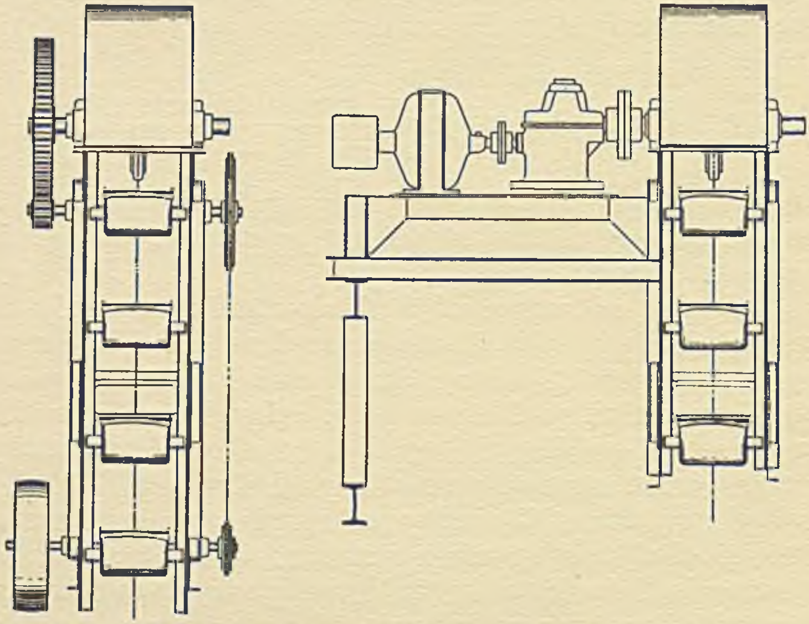


FIG. 116.—Alternative Drives to Elevator.

It is thus easy to reduce from a motor running 2000 revolutions per minute to a slow shaft running only 5 revolutions per minute or less, using a relatively cheap and compact motor.

The torques on the slow-speed shaft of a Hatcher or Stone's gearbox for a speed of 10 revolutions per minute range from 275 to 170,000 inch-pounds in the various standard sizes; but as the speed goes up the allowable torque on any particular size of gear goes down, and vice versa.

A word of warning is necessary to ensure that a size of gear be selected well above the rated size, otherwise there will be trouble from serious overheating. This requirement means high first cost but low maintenance charges.

The application of a high-speed motor drive to an elevator utilising an H.R. reduction gear is shown in Fig. 116. This design is an alternative to the use of a slower motor with belt drive, chain and spur reduction gear, as shown in the same figure.

In dealing with slow speeds of revolution it is much safer to work with torques than with powers, at least as regards strength. There is a simple relation between these quantities, the power transmitted by a shaft being the product of the torque and the speed, using the correct units of measurement.

Suppose we have a gear-wheel of r inches radius keyed on to a conveyor main shaft, and that a force of F pounds is applied at the pitch circle, the speed being R revolutions per minute. Then the work done per minute is the force multiplied by the space through which it is exerted, or

$$\text{WORK} = F \times \frac{2\pi r}{12} \times R.$$

But the torque T, expressed in inch-pounds, is Fr. Therefore work done per minute is

$$\frac{2\pi}{12}\,TR.$$

Hence the horse-power (P) is

$$\frac{3\cdot14}{6 \times 33000}\,T \times R,$$

or the torque
$$T = \frac{198000}{3\cdot14} \times \frac{P}{R},$$

which is approximately 63,000 times the ratio of the horse-power transmitted by the shaft to its revolutions per minute.

For example, if the power required at the slow-speed shaft is 10 H.P. at a speed of 5 revolutions per minute, the corresponding torque on the shaft will be $63{,}000 \times \frac{10}{5}$, or 126,000 inch-pounds. This means a large and expensive reducing gear if of the Stone's type; but, on the other hand, the motor can be relatively small if run at a high speed.

Although it is the ratio of horse-power to the speed which governs the torque, it must not be forgotten that the heat generated by friction increases both with the power and the speed, so that for the same torque the risk of overheating the gear is much greater with a high-power and high-speed gearbox than in the case of a low-power and slow-speed box.

After having found the torque at the main shaft of a conveyor, it is necessary to know the *efficiency* of transmission before we can calculate the power required at the high-speed shaft coupled to the motor. Makers are prone to be unduly optimistic in regard to the actual efficiency of reducing gears, but for power calculations it is wiser to underestimate the efficiency rather than to exaggerate it.

It is alleged that the mechanical efficiency of an H.R. reduction gear varies from 70 up to 90 per cent. in gears having ratios up to 250 to 1, and that this high efficiency is maintained throughout the life of the gear. This is open to question, but if we take the lower figure 0·7 as the ratio of the power output to the power input, then the brake horse-power of the motor coupled to the high-speed shaft will be the power at the slow shaft divided by the efficiency of the gear. In the above case this becomes $10 \div 0{\cdot}7$ or 14·3, or let us say 15 H.P.

When using a Stone's gearbox it is considered economical to adopt a rather high-speed motor and a large ratio of reduction, in order that the high first cost of the gear may be compensated in some measure by the saving in the cost of the electric motor, as well as for the sake of economy of space.

The motor and the gear should preferably be mounted on a common bedplate, tied to the conveyor framing, and secured to a good foundation. There should also be a flexible coupling between the motor and the input shaft, and another between the output shaft and the main shaft of the conveyor ; thus eliminating bending moments from the shafts as far as possible. The bearings should be of the ball type for the high-speed shafts, and of the roller type in the case of the conveyor shaft, all self-aligning, thus reducing the friction to a minimum.

An Instructive Conveyor Drive through Fluid Coupling.—In the year 1933 a 30-inch slat conveyor having the exceptional length of 800 feet centres for rapidly transporting 2-cwt. bags of granulated sugar from warehouse to wharf was erected at one of the East London refineries of Tate & Lyle Ltd. This and its twin brother forms a fine example of conveyor engineering (see Plate II). When started up one conveyor was driven temporarily by a 24 H.P. motor of the squirrel-cage type, which the users happened to have available from stock. This was fed by 3-phase current of 220 volts and the low periodicity of 25 cycles per second.

The conditions of working at first were such that the conveyor had to be very frequently started and stopped when fully loaded with sugar, the total mass to be accelerated amounting to some 60 tons. Since force equals mass times acceleration, assuming the period of acceleration to be one second in attaining a chain speed of 60 feet per minute, this meant an inertia resistance alone of about 2 tons, to overcome which and the frictional resistance a heavy starting torque was required. It was noticed that the kick on the ammeter needle showed a momentary starting current of some ten times the current at the steady running load. Obviously this meant a severe shock on the transmission, which was bad not only for the motor and the line but also for the conveyor chains and the driving gear.

To some extent the high initial starting effort and shock could be reduced or smoothed out by means of a Bibby resilient coupling, with its effective grid spring placed between the electric motor and the gears. The application of a centrifugal friction clutch on the motor shaft to give a gradual pick-up was also thought of but not adopted.

It is useful to note, however, that the torque of a centrifugal clutch increases as the square of the revolutions and that the horse-power varies as the cube of the speed. The mass of the shoes also has an influence on the capacity, the horse-power being directly proportional to their weight. When the torque is expressed in inch-pounds and the speed in revolutions per minute,

$$\text{Horse-power} = \text{torque} \times \text{speed} \div 63{,}000.$$

A third alternative cushioning device thought of was the ingenious and simple automatic " Pulvis " clutch containing fine shot, and adjustable for either slower or quicker pick-up according to the amount of shot contained. Here the shot may be regarded as a semi-fluid. Any of these shock-reducers could, of course, be combined with a mechanical speed-varying device to get the desired result of a cushioned and variable speed drive.

In the conveyor drive under consideration, as both direct and alternating current were available at the site a change was soon made experimentally to a stock direct-current motor ; which not only had a better starting torque than the squirrel-cage motor but also permitted of a variable speed control. The latter was found to be a highly desirable feature on account of the variable conditions of working when the bags delivered by the conveyor down a swivelling chute were being picked up in batches of twelve by means of a cantilever transporter crane and delivered into coasting ships and barges moored at various distances from the wharf.

After taking ammeter readings at various speeds of the conveyor it was decided that a 16 B.H.P. motor was of sufficient size to do the work, whereupon a slip-ring induction motor was ordered, as being more suitable than a squirrel-cage motor for starting up on full load and also giving a better power factor. A motor speed of 700 revolutions per minute gave the desired conveyor speed of 60 feet per minute, with a total reduction ratio of 88 to 1 in three stages of reduction by belt and spur gears.

Meanwhile the author had been studying the possibilities of various types of variable-speed gears, both mechanical and hydraulic. These included the old and well-tried Reeves' frictional gear with expanding and contracting conical pulleys, also the positively infinitely variable (P.I.V.) gear working on a similar kinematic principle but without slip.

Other possible alternatives were the permanent use of a direct-current motor with a variable resistance in the shunt circuit, or even a 3-phase alternating current commutator motor of the variable-speed type, having the position of the system of brushes controlled from a distance by a small servo-motor. Though the first cost of such a shifting-brush alternating current commutator motor is extremely high, it certainly has some attractive features, and doubtless has a great future for some applications, such as cage-winding in mines.

Finally, a Vulcan-Sinclair fluid coupling of the scoop-tube type (Fig. 117) [1] was adopted for the following reasons :—

1. It was easy to apply to the existing driving gear.
2. It eliminated all starting shock from the conveyor chains and mechanism by greatly prolonging the period of acceleration and thus forming a wonderfully flexible connexion between the electric motor and the load.
3. It permitted of a simple method of adjusting the speed of the conveyor to suit frequently varying conditions of working.
4. Distant control of speed was feasible by means of push-button switchgear and a small servo-motor operating a simple oil-pump of the gear type.

After introducing a fluid coupling there is, of course, no absolute need to depart from the ruggedness, the simplicity and the cheapness of a squirrel-cage motor, though actually in the present case the 16 H.P. slip-ring motor that had already been made was utilised. This motor was mounted on a simple fabricated bedplate, together with a Vulcan-Sinclair coupling of 26 inches outside diameter and a roller bearing on each side of the belt pulley. It is important that the pull of the belt should be taken in this way, to ensure that the coupling shall have only pure torque to transmit. Correct alignment must also be ensured.

The impeller or driving half is of cast iron, secured to the motor shaft, whilst the inner and outer casings are made of high tensile aluminium alloy and bolted to the impeller, the whole rotating as one mass. The runner or driven half is of cast iron, keyed to a stub shaft terminating in a flange for coupling up to the driven shaft. There is no actual contact between the impeller and the runner, both of which have numerous radial vanes cast on. In fact there is a clearance or gap of nearly $\frac{1}{4}$ inch between them, which is bridged by a series of whirling jets of oil moving at high velocity.

The stationary scoop tube is made of steel and is bolted to a fixed cast-iron housing integral with the oil-supply tank

[1] This illustration is taken from a paper by Harold Sinclair on "Recent Developments in Hydraulic Couplings," read April 1935 before the Institution of Mechanical Engineers.

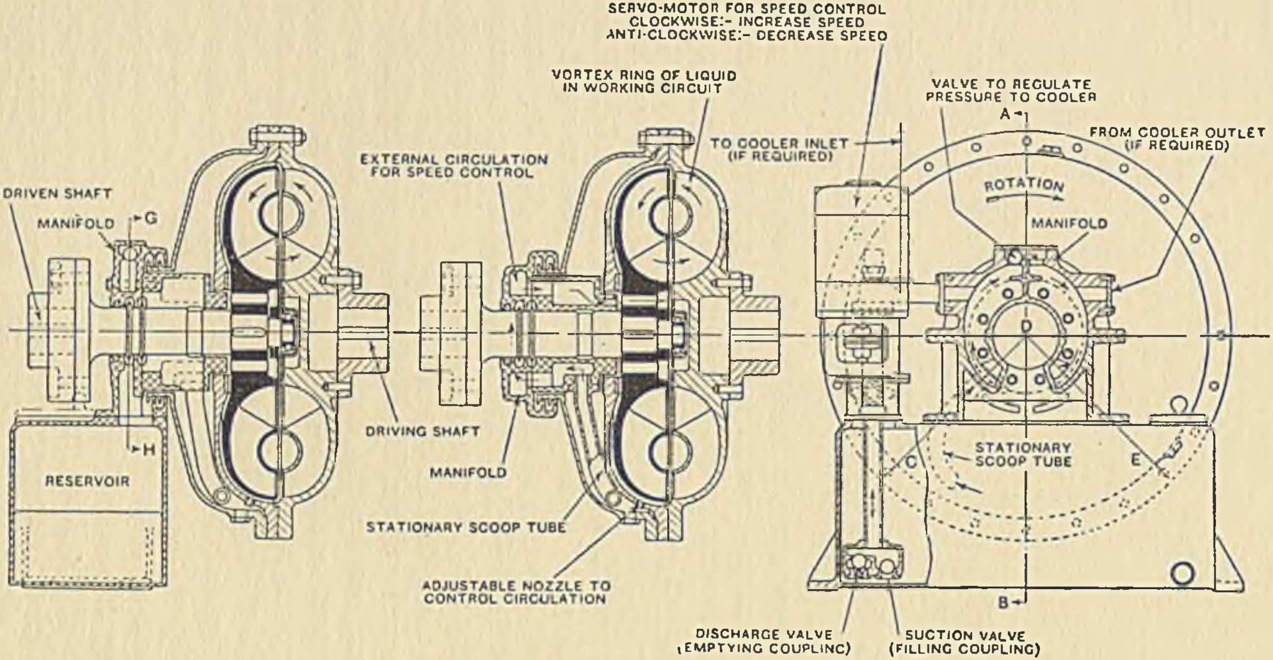


FIG. 117.—Hydraulic Variable Speed Coupling.

which rests on the bedplate. Speed control is effected by means of a simple gear pump mounted on the oil tank and operated either by a hand wheel, as in the first set tried, or by remote control, as in the second set. Clockwise rotation of the control wheel circulates some of the oil through ports in the manifold and increases the quantity in the working circuit. This reduces the slip and the speed increases. Anti-clockwise rotation of the control wheel removes oil from the working circuit; thus allowing the slip to increase, and the speed of the runner falls. The coupling may be completely emptied when at rest, in order to ensure the lightest possible starting load on the motor, but it is not necessary otherwise, and in fact is not done in the present case in regular working.

This first hydraulic coupling that was ever adapted to a conveyor drive proved very successful and has been in daily operation since the first week of January 1934. After a month's trial it was decided to fit the twin conveyor with a similar coupling but equipped with remote speed control. This coupling functions satisfactorily, gives no trouble, and will undoubtedly prolong the life of the conveyor chains and transmission gear, thus proving a good investment of capital. Also it is easy now to hold back the sugar bags when they are coming along too quickly to be handled, and to speed up delivery when there is a temporary lull.

A few remarks on conveyor drives in general may fitly conclude this section. The consideration of alternatives is always instructive and may be helpfully suggestive. A conveyor engineer has to be ready to supply any type of driving gear that may be called for. One executive engineer, according to his individual experiences, will specify plain cut gears and nothing else will be tolerated, in consequence of his having experienced some trouble with perhaps worm-reduction gears. Another executive engineer will prefer worm boxes, on account of their superior cleanliness and compactness. He may even insist on a particular make and size, for the sake of interchangeability with existing gears, even if the latter should be somewhat in excess of actual needs, because a duplicate is regularly kept in stock available for immediate substitution in case of a breakdown. These are very important practical considerations in a busy factory.

Another engineer may have a particular fancy for, say, the H.R. gear, an extremely compact form of a series of three worm-reduction sets enclosed in one box, most suitable for big reduction ratios. More recently there have become available on a commercial basis the dwarf form of worm box, with air-cooling fins and fan to prevent overheating, known as the " Radicon Reducer," which though small is of high load-carrying capacity. There is also the ingenious " Heliocentric Reducer," which is capable of any ratio of reduction between 16 to 1 as a minimum up to any figure required as a maximum. Thus there is ample choice of alternatives in the way of mechanical speed-reducing gears.

Any of these forms can be combined with either mechanical or hydraulic or electric speed-varying devices, together with flexible couplings to reduce shocks. For example, one might arrange quite compactly on a common bedplate and coaxially a high-speed squirrel-cage motor, a fluid coupling with speed variation, a heliocentric reducing gear and a flexible coupling between the output shaft and the conveyor main shaft. Thus we should get all the needful technical characteristics of a good conveyor drive, viz., flexibility, speed reduction and variation and compactness. But the first cost might be prohibitive in open competition, as compared with an inferior drive, and something cheaper might have to be substituted, since many buyers would doubtless regard the fluid coupling as a needless luxury.

CHAPTER XIV

CONVEYORS IN RELATION TO THE FOUNDRY INDUSTRY

(*a*) **Introduction.**—Instead of the subject of conveying machinery being considered generally, it could be studied in relation to certain specific industries individually. Amongst such industries using conveyors might be mentioned those devoted to the production of beer, of cement, of castings, of chemicals, of coals, of gas, of motor cars, of ores, of sugar, of radio sets and of textile fabrics.

Now, adequately to describe the application of conveyors to each and all of those extensive industries would obviously demand far more space than is available in these pages. So, from amongst this amplitude of choice, one industry only will be selected for special consideration, namely, the foundry industry, or that dealing with the production of ferrous castings (of manifold forms, sizes and uses) from pig-iron, scrap, sand and other raw materials.

In considering the history of the development of conveyors in general, it cannot truthfully be said that the foundry industry was one of the earliest to benefit by the application of conveyors to the economical movement of raw materials, intermediate products and finished work. Long before conveyors were adopted in foundries they were a common means of transport in grain silos, in flour mills, in sugar refineries, in gasworks and in the mining industry.

Indeed, even to-day, it is only in those foundries which are engaged in repetition work on a large scale, or on quantity production, that conveyors find much favour. Alternative means of handling by cranes of various types, also by pulley-blocks, air lifts and hoists, by telphers, electric trucks, petrol trucks, and even by hand barrows, trucks, bogies and rollers are still of more frequent application and of greater flexibility than are continuous conveyors and elevators.

In this connexion one's thoughts turn naturally to the great automobile industry, where the necessity for producing a constant stream of similar castings for motor cars and commercial vehicles demands the convenience and economy not only of conveying machinery but also of mechanical-handling appliances of every kind. Probably in no other section of the foundry industry are continuous conveyors so extensively employed.

Another repetition line where conveyors have been found of much service is the manufacture of cast-iron radiator sections for steam and hot-water heating units, whilst a third is the production of cast-iron pipes for gas and water on a large scale by centrifugal casting, as practised by the Stanton Ironworks and the works of the Staveley Iron and Coal Co. Ltd., Derbyshire.

Undoubtedly of recent years much attention has been directed to the question of the preparation and economic transport of sand in and about foundries and coreshops, as workshop units have continued to increase in size. Such melting capacities as 1000 tons of iron per day in one vast American foundry have been recorded, necessitating an enormously increased rate of pouring and output per foot of floor space. Under suitable conditions conveyors greatly reduce the cost of handling and permit of a larger output with a given expenditure of labour on a limited floor space.

Conveyors of many types are employed in foundries for transporting such diverse materials as pig-iron and scrap, coke, coal-dust, sand, cores, castings and rubbish. These types include both spaced and continuous-bucket elevators, vertical or inclined, with either belts or chains, also tipping-bucket chain conveyors and overlapping tray conveyors. There are also in use belt conveyors with either canvas, rubber or steel ribbon belts, scraper or push-plate conveyors with roller flights, steel-plate or slat conveyors, drag-link and trough conveyors, short spiral or worm conveyors and gravity roller conveyors. Further, the pneumatic system of moving fine materials by air current in pipe lines finds application in some foundries.

(*b*) **The Charging of Cupolas and Furnaces.**—Taking the cupola as the starting point in the production of grey-iron castings, the method of charging or feeding it with pig-iron, scrap and coke is our first consideration. Although the intermittent service of a motor-driven cage hoist, taking up barrows or tray loads of stuff at intervals, is by far the most common method in vogue of raising raw materials to the charging platform, nevertheless the inclined continuous-bucket elevator has been successfully applied in a few instances, as, for example, at the foundry of Fodens Ltd., Sandbach. This elevator of 26-feet centres has overlapping steel buckets 18 inches long, bolted to a single strand of heavy Ley bushed chain of 12-inch pitch. It is driven through double-reduction spur gearing by a very small motor, since continuous elevators absorb extremely little power. A second example, from Glasgow, is shown in the view, Plate XIV.

Yet it must be admitted that such instances of the use of bucket elevators for serving cupolas are extremely rare. The reason is not immediately obvious, except that the service required is not really continuous. Perhaps it is also because of the relative ease with which materials may be weighed when in trays or in barrows, and then combined in correct measured proportions to produce the right mixture. There cannot be much difference in capital cost and in labour costs between the two types of lifting machines.

Turning now to the malleable iron foundry industry, the usual manual method of charging a small reverberatory or air furnace is for relays, or a gang of men working in series, to throw the broken pigs and trays of hard scrap into the furnace from a temporary staging, after having hoisted clear a few sections of the arched furnace roof, which is always built up in the form of a series of cast-iron bungs lined with firebricks. Little or no mechanism is employed in actually charging such furnaces up to those of 10-ton melting capacity; but in the case of the big 20-ton furnaces in the latest foundries of Ley's Malleable Castings Co. Ltd., Derby (which are exceptionally well equipped with mechanical appliances of every kind), special electric overhead travellers are utilised for handling the large tipping-skips containing the furnace charges.

The fuel burnt by these modern melting furnaces is pulverised coal containing a low percentage of ash. The preparation of this fuel from raw coal and its transport to the furnaces involves the use of quite a number of conveyors and elevators, as well as fans and air currents moving in long pipes.

At Derby the raw coal, preferably washed beans, is discharged from railway trucks into a receiving hopper situated below the rails, and flows on to a short belt-conveyor, which feeds a pair of vertical elevators of 60 feet centres, having 8-inch buckets bolted to Ley bushed chain of 3-inch pitch, delivering to a spiral distributing conveyor placed at a high level over a range of three coal-storage silos.

Other units in this pulverised-fuel plant convey raw coal from these silos to a revolving dryer, after treatment in which a drag-link conveyor takes the now thoroughly dried coal to the grinding mills, whence the coal-dust flows pneumatically into a pair of powdered-coal storage bins. A series of spiral feeders below these bins are connected up to the primary air pipes serving the melting furnaces and the annealing ovens, all of which are situated some considerable distance away from the centralised coal-grinding plant. Thus the pneumatic system of transport of fuel by means of fans and pipes to the furnaces is here successfully employed.[1]

In the case of the smaller hand-fired reverberatory furnaces in the same works, electric accumulator trucks equipped with tipping bodies are utilised for the transport of hard lumpy coal from the stockyard to the furnaces arranged down the middle of one foundry. This method has been in use for some twenty-five years.

(*c*) **Transport of Sand.**—The transport of moulding sand from the sand-milling plant to the moulds, though often done entirely by hand-labour, using shovels and barrows, is capable of being performed by a bucket-elevator and a push-plate conveyor; in which case it is only necessary for the machine moulder to pull a chain to get a supply of sand delivered to his side or into the moulding box on his machine. Naturally, such a sand conveyor would not prove an economic proposition unless a considerable number of moulding machines were arranged in a row and there was a fairly steady demand for sand.

A practical drawback to this conveyor scheme was that the sand was supplied with such facility to the moulder that he became extravagant in the use of facing sand. Also, the

[1] See a fully descriptive article in *Engineering* of 28th August 1936.

wear and tear on the plant was somewhat heavy, owing to the cutting action of the sand. Consequently the alternative method of intermittently supplying the moulder with loads of sand from hand-barrows or from electric trucks fitted with tipping bodies was preferred, as being more flexible and also more economical in sand consumption. The petrol trucks tried, though quicker in getting about, were found to be more frequently in the repair shop than were electric accumulator trucks when working under dusty foundry conditions, and so did not long survive.

In the modern type of moulding machine, known as the tractor type of sand-slinger, a complete system of three small conveyors is included in the machine itself, which is almost imperceptibly traversed over the foundry floor by a rack feed, the entire mechanism being motor-driven.

The sand, having been prepared on the floor in a long heap straddled by the machine, is gradually nibbled into by a worm conveyor with right and left hand spirals, and fed to a vertical bucket elevator delivering through a shaking chute on to a short band conveyor serving a fast-running impeller, which discharges the sand at a high velocity into the moulding boxes coupled to the machine. No ramming is required other than that supplied by the kinetic energy of the sand jet. Some other types of heavy moulding machines, besides sand-slingers, have bucket elevators associated with them for quickly filling large moulds.

In a large Sheffield steel foundry the moulds are emptied out over a long bar-grid at floor level, by means of a special travelling crane. This grid intercepts the castings, while allowing the used sand to fall through the bars into a long 30-inch tray conveyor contained in a trench. This tray conveyor, of 303 feet centres, is slowly driven by a variable-speed motor through an enclosed triple-worm reduction gear. It delivers into an inclined elevator with 36-inch continuous buckets, feeding a sand-screening plant fixed at a high level.

During the year 1931 a Midland foundry producing rain-water fittings installed an interesting plant, shown in elevation in Fig. 118. There is a double-service mould conveyor A on which the moulding boxes travel round to the grid B at one end and are knocked out whilst still hot. The sand

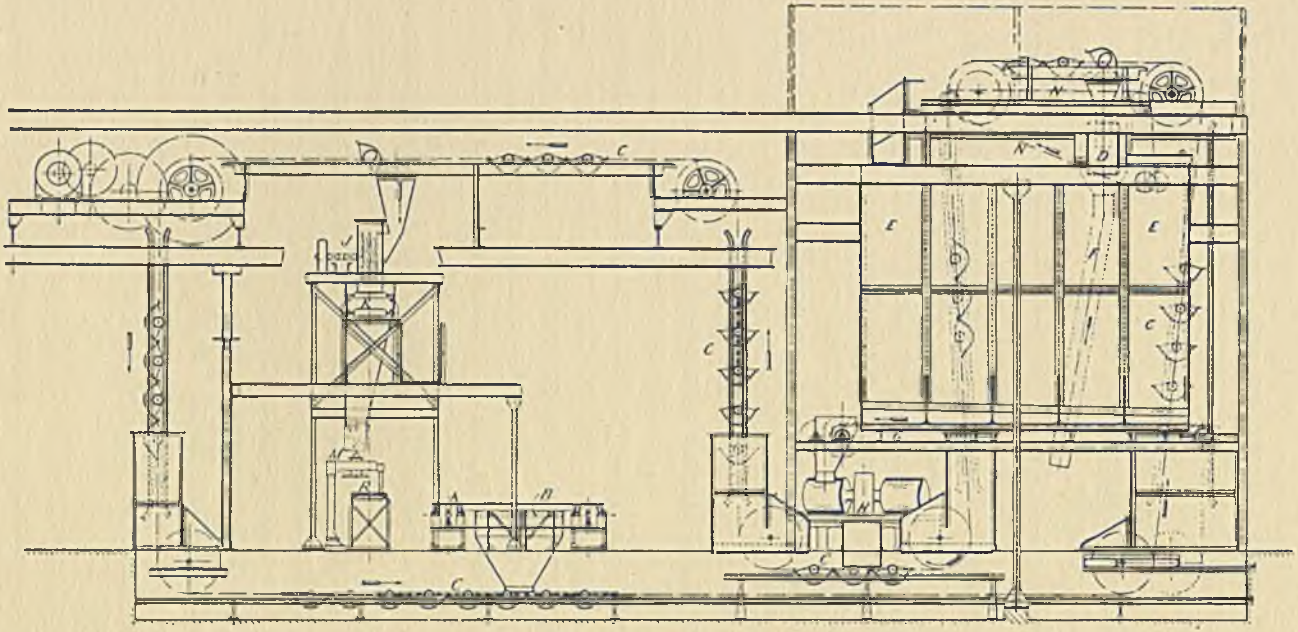


FIG. 118.—Continuous Sand Handling Plant.

falls into the gravity-bucket conveyor C fitted with 16-inch overlapping buckets, by which it is taken up and deposited on the short inclined band conveyor D, which in turn feeds into the sand-storage hopper E. This short band conveyor is fitted with a magnetic end-drum for removing pieces of iron, which are discharged clear of the conveyor through a long receiving chute F.

The sand is extracted from the storage hopper E by means of an apron-type corrugated-slat conveyor, and is delivered to the Ronceray continuous sand mill H, where a certain amount of water is added to the sand. At H the sand is ploughed off the mill-plate on to the return strand of the gravity-bucket conveyor, which elevates it and delivers to a reel-type aerator J. From the latter the sand goes to the main band conveyor K, whence it is ploughed off into the hoppers over the moulding machines and the core-making machines.

A point of some novelty is that a very simple type of scraper conveyor is employed to spread or trim the sand inside the storage hoppers in order to utilise their maximum storage capacity. The gravity-bucket conveyor itself is capable of handling 30 tons of sand per hour and measures some 200 feet round the circuit. All the other units are designed for a capacity of 15 tons per hour; the intention being to duplicate the sand-preparation plant later, utilising the existing gravity-bucket conveyor as the main feed.

(*d*) **Transport of Foundry Refuse.**—Foundry refuse and waste sand can be conveniently removed from the works by employing a continuous-bucket elevator to pick up the waste material dumped by barrows and trucks into the bottom boot of an elevator, delivering the stuff from the chain of buckets into an overhead storage hopper; whence the contents at intervals can be discharged into carts, motor trucks or railway wagons with a minimum of labour and loss of time. Alternatively a skip hoist can be used.

Plate VII represents a portable bucket elevator taken in a foundry yard when engaged in filling a steam lorry with sand and refuse. Though this is an advance on the spade-work of a gang of men, and less dusty, the absence of an overhead storage hopper means that this method of loading holds up the lorry and keeps it off the road for quite a time.

As an alternative a portable inclined belt conveyor may be used.

Two other methods of filling carts and trucks economically may be briefly mentioned. One is a motor-driven skip hoist, used either with or without a storage hopper, as indicated in Fig. 119. For coarse cutting material this is better than a continuous elevator, in which the renewals are heavy. Best

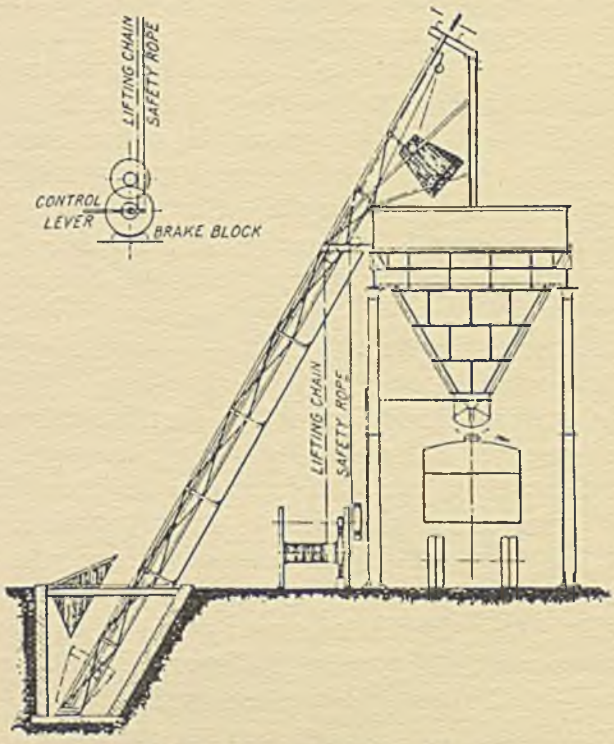


Fig. 119.—Skip Hoist for Ashes.

of all, however, is a mechanical shovel, mounted on a Fordson petrol tractor, forming a very mobile and rapid means of loading bulk materials from a heap with a minimum of labour. Such a shovel operated by one man and made by the Chase-side Engineering Co., Enfield, has given good service in the yard of Ley's Malleable Castings Co. Ltd., Derby, quickly filling motor lorries with spent sand and other foundry rubbish from three loading stations in different parts of the yard.

(*e*) **Handling Core Sand and Cores.**—In a large foundry engaged on repetition work the preparation and transport of the core sand and the cores is quite a big thing in itself, presenting an increasing field for the application of mechanical appliances. In Ley's core shop the clean sand is raised to storage hoppers by a pair of bucket elevators and discharged into a series of mixers, where the binding material is

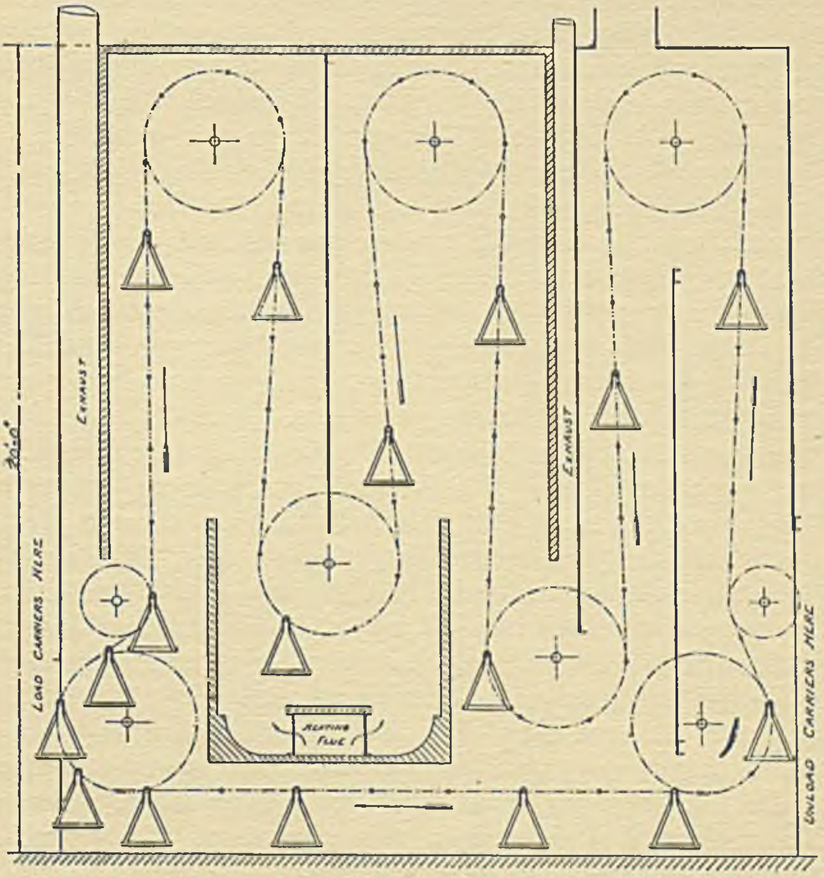


FIG. 120.—Diagrammatic Layout of Core Dryer.

thoroughly incorporated. Formerly the undried cores were handled by lifting trucks serving intermittent core stoves. But these trucks have been displaced by a continuous steel-belt conveyor, 24 inches wide by 0·04 inches thick, by 200 feet centres, speed 10 feet per minute, and the old core stoves by a pair of continuous core dryers.

This type of core dryer is essentially a slowly moving double-strand swing-tray conveyor with a triple loop of chain in elevation, the whole of the running gear being enclosed in a sheet-steel casing and fired by coke. As seen in Fig. 120, the soft cores are fed in on the rising side of the first loop house in the preheating or preliminary drying chamber; they are then carried by the second loop through the final drying chamber, which completes the baking of the cores; and, lastly, they pass through a separate cooling section, independently ventilated. The hard-baked cores are removed on the falling side of the third loop, by which time they are cool enough to handle. This core dryer was made by the Foundry and Engineering Co. Ltd., of West Bromwich.

As a core shop is often a detached building somewhat remote from the foundry proper, the method of delivering the cores to the various moulders scattered over a large foundry is a matter of serious consideration, especially as cores are friable and easily damaged by rough handling. Amongst the means employed are hand trucks, electric and petrol trucks and continuous conveyors.

A recent example of a core conveyor is shown in Plate XVI (see page 145), the photographs having been taken at the works of Qualcast Ltd., Derby. This conveyor is of the double-service type, rectangular in plan view, 114 feet by 44 feet 6 inches centres, with a chain length of 314 feet, and having special curved steel slats 24 inches wide on a 24-inch pitch malleable iron chain, thus forming a continuous table 30 inches high, on which the cores rest. It traverses the whole of the core shop and connects a continuous vertical core-drying stove to the foundry, passing on its way a number of short benches on which the core-makers work. Female labour alone is employed in this core shop. This special conveyor was designed and constructed by the Ewart Chain-belt Co. Ltd. It is driven by a motor of 3 H.P., running at 940 revolutions per minute through a variable-speed gear and double-reduction enclosed worm gear, having a velocity ratio of 775 to 1. The chain speed can be varied from a minimum of 10 feet per minute to a maximum of 40 feet per minute.

(*f*) **Mould Conveyors.**—Although most foundries still follow the age-long practice of carrying molten iron to the moulds, either in small ladles (shanks) by hand or in big trunnion ladles by means of a crane or a runway, there are nevertheless a few repetition foundries where this process is reversed and the moulds are carried to the iron, thus permitting of continuous pouring, whilst economising both time and energy. Carrying molten iron by hand any distance is far from being a pleasant job.

In different foundries three types of conveyors are utilised for this purpose, namely, the double-service slat type, the overhead monorail sling type and the slightly inclined gravity type.

One of the earliest adaptations of the continuous-chain conveyor is that installed over forty years ago by the Link-Belt Co. in the foundry of the Westinghouse Air Brake Co., Wilmerding, Pennsylvania. This double-service flask conveyor was made of 227 feet centres and carried green sand moulds smoothly along without jarring.

A good example nearer home of the double-service type of mould conveyor with modern improvements, though perhaps only one-third the length, is that installed in a section of the iron foundry of the Davis Gas Stove Co., Luton. The castings made in this section are mostly shallow and uncored, which simplifies matters. The whole plant is very compact and efficient; the saving in floor space and increase in production by continuous melting and casting being enormous.

At Luton a row of some seven moulding machines is arranged on the side of the conveyor remote from the cupola. A short overhead runway connects the cupola to the pouring platform at the tension end of the conveyor, two men doing all the pouring from hand ladles. At the driving end two other men drag the boxes off the conveyor and empty them over a fixed grid, at once replacing the empty boxes on the conveyor and transferring the red-hot castings, while the sand drops below. The latter is then raised by a vertical elevator to a sand-screening plant, and when reconditioned or revivified the sand is handled by a second elevator and a horizontal band conveyor, which feeds the moulding machines.

More recently there has been installed at the Derby works of International Combustion Ltd. a successful continuous mould conveyor served by thirteen moulding machines, which is normally in operation from 8 A.M. to 5.30 P.M. for five days a week, the output being 25 tons per day. Here the castings vary in weight from a few ounces to about 40 pounds, perhaps one-third of them being cored, many of them weighing 8 pounds. The cores are put into the moulds before the latter are placed on the conveyor. The operations of melting the iron in cupolas and pouring the molten metal from ladles slung from a runway proceed continuously.

This conveyor was made by Herbert Morris Ltd., Loughborough. The drive is through a P.I.V. gear, the chain speed normally varying from 10 to 15 feet per minute. The number of boxes put down by each moulder varies between

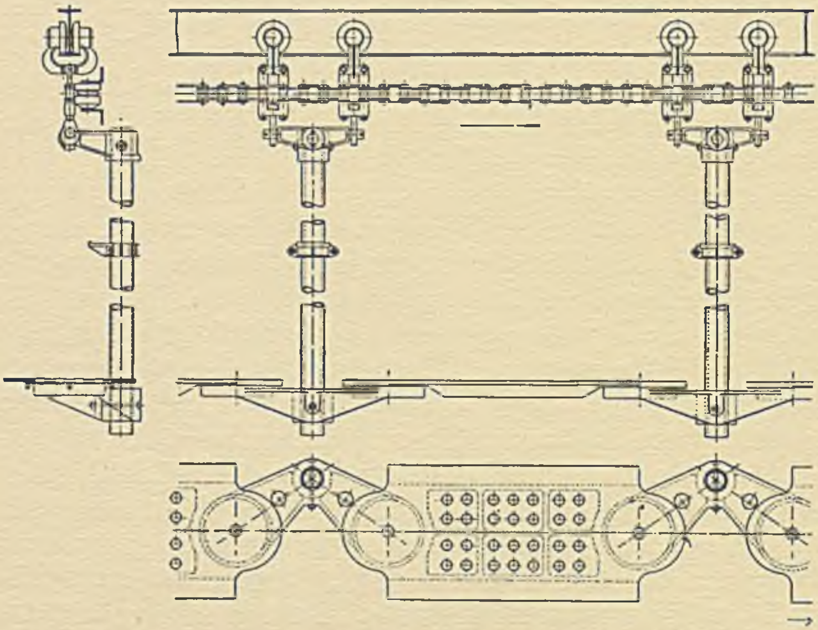


FIG. 121.—Ford Type of Mould Conveyor.

300 and 370 per day, some of the moulds being made in less than a minute. The percentage of scrap is not high, in fact it is said to be 2 per cent. less than with hand moulding.

A well known early application of the overhead sling or pendulum type of conveyor to the handling of moulds was that installed by the Link-Belt Co. in the River Rouge Foundry of the Ford Motor Co., which the writer was privileged to view when visiting Detroit in the year 1923.

This type consists essentially of an overhead track or monorail carrying a series of light trolleys connected to an endless chain, driven by a sprocket wheel and suitable reduction gearing, preferably at a variable speed. From the trolleys are slung the mould carriers or "pendulums" linked together and coming down to a convenient level about 1 foot above the floor, to permit of pouring the moulds from hand ladles. The ladles do not need to move far from the source of supply of molten metal, whether that source be the cupola itself or a fixed receiver or a main ladle suspended from a crane or a runway.

In Fig. 121 is shown a recent example of the Ford type of mould conveyor, as erected at the Dagenham foundry of the Ford Motor Co. by Bagshawe & Co. Ltd., Dunstable. There are four of these conveyors, each of about 620 feet run. The average weight of the chains, trolleys and mould carriers or "pendulums" is 32 tons on each conveyor, whilst the calculated load (moulding boxes, sand and castings) approaches 58 tons, thus giving a total moving mass of about 90 tons. The minimum speeds of the conveyors range from 8½ to 17½ feet per minute, but variable-speed motors (in duplicate) give a possible increase of 50 per cent. on these speeds. Yet the power required to drive such a conveyor is quite small, viz., only 6 H.P.

(*g*) **Transport of Castings.**—In the extensive works of Ley's Malleable Castings Co. Ltd. the castings are taken from one of the foundries to the cleaning shops by means of electric trucks running on the ground, and from another foundry by an overhead electric telpher system. In the latter case the castings are collected in steel tubs, five of which are lifted at once by the hoisting gear from the foundry floor, then run out of the foundry and over the yard on a fixed track, furnished with suitable crossings and switches. In each case one man only is required to move a ton or more of castings. As regards low upkeep per ton of castings moved, the advantage is with the telpher. In addition, the use of a number of capacious steel barrows, serving partly as convenient temporary receivers for castings, cannot well be avoided.

When at Detroit in 1923 visiting the Highland Park factory of the Ford Motor Co., a point of interest noted was the fact that the motor-piston castings came direct from the foundry to the machine shop in a continuous single file, slung from an overhead monorail chain conveyor, so arranged that the turner had only to raise his hand to get hold of a piston casting, without moving from his lathe. As the machined pistons were also removed by means of another conveyor there was no unnecessary putting down and picking up again, but a constant flow of material, time and floor space being economised to the utmost extent.

Of recent years there has been a considerable development in overhead monorail conveyors in many industries. Standard biflex chains are made which permit of motion in two planes at right angles to one another, thus curves and inclines can be negotiated without difficulty and obstructions surmounted. Such conveyors, however, are more common in machine-assembly shops than in foundries.

Small castings which have to be annealed, cleaned and sorted are most conveniently transported in hand-barrows or in trays on bogies, for it is necessary that they should be kept in batches and not all mixed up together when passing through the grinding and fettling shops, prior to being received and weighed into the shipping room. Bulk transport by continuous conveyors is inapplicable where the service requirements are of an intermittent character and a steady flow of material in one direction impossible.

An important supplement on "Modern Foundry Equipment" appeared in *The Engineer* of 28th May 1937; where continuous-mould conveyors and sand-handling plants are described.

CHAPTER XV

CONVEYOR INQUIRIES AND PROPOSALS

Inquiry Questionnaire.—It is not possible to prepare a suitable design and tender in response to an inquiry without a full knowledge of the requirements, unless liberal assumptions are made which may turn out to be incorrect.

Possibly a representative may be asked to call and study the requirements on the spot in conference with a responsible official, as it may not be feasible to formulate a proper inquiry specification until after a discussion with a technical expert.

Inquiries for conveying plant should preferably furnish answers to the following queries :—

1. If bulk material has to be handled, what are its physical characteristics, such as whether dry or wet, fine or lumpy, range of sizes of pieces, weight per cubic foot, whether free-flowing or viscous and so on ?
2. If packages have to be handled, what are their sizes and weights, nature of contents, type of container (box, crate, carton, tin, bag, cask), whether roll, loose bundle or parcel ?
3. What is the maximum required duty or carrying capacity per hour, expressed either in tons or in number of packages ? Is the rate of feeding uniform or very variable ? If the latter, a speed-varying gear is indicated. In package elevators of the swing-tray type the chain speed should not exceed 60 feet per minute, while 40 feet is the usual speed. To increase the capacity it is better to put the carriers closer together than to run fast.
4. How has the conveyor or elevator to be fed : by hand, barrow, truck, feed hopper, jigging feeder, apron feeder, or by another conveyor ?

5. Where has the load to be discharged : over the end only or at several other points ? Are swivelling chutes wanted ?
6. How can the conveyor be supported : from existing walls or a structure or by trestles, tower, bridge or gantry ? What access ladders and platforms are wanted ?
7. How will the conveyor be driven : by belt or chain from an existing shaft ? If so, state position, size, speed and direction of rotation. Or by a steam or gas or oil engine ? Or by an electric motor ? Give particulars of the steam pressure available or the voltage of the current as well as the periodicity if 3-phase alternating current is supplied. Has the engine or the motor to be included, also switchgear ? Is there any preferred maker ?
8. Is all the erection labour to be included or only skilled labour ? Foundation and builders' work are usually excluded.
9. Is the site readily accessible by road or rail, and is there a definite limit to the size of the parts, dictated by existing wall openings, bridges or tunnels ?
10. Is a first-class job wanted of maximum durability, or will a light cheap job for only temporary service suffice ?

A drawing of the site or even a very rough sketch is always helpful to the designer. The general layout must fully take into account the needs of a systematic flow of production, in contradistinction to haphazard jumping about from one stage to another ; the latter always involving waste of movement, time and energy.

Preparing a Proposal.—Having obtained all the information he needs, the estimating draughtsman proceeds to get out a design. In other words, he makes an outline drawing sufficient for estimating purposes and giving a general idea of the nature of the proposal. Certain details may have to be worked out on separate sheets to a larger scale.

Concurrently with the preparation of the estimate drawing, various calculations will have to be made as to capacities, speeds, stresses, bending moments, strengths, torques and powers; in order to determine the sizes of the details by the application of the ordinary rules and principles of applied mechanics. Reference may also be made to technical data sheets, graphs and drawings of completed plants of similar character. Although nothing should be left to guesswork wherever calculation is feasible, much will have to be settled from previous experience.

The next step is to take out the quantities, preferably grouped in several sections. This means making a long list or schedule of all the details, often covering several foolscap sheets of paper, containing separate columns for names and sizes of details, numbers required, weights, rates and costs.

In the case of an open lattice-framed bucket elevator, for example, the sections or groupings might be as follows :—

1. Running gear: including chains, wheels, buckets, skidders and bolts.
2. Driving and tension gear: including shafts, bearings, gears, tension screws, etc.
3. Steel framing, head, boot and dust trough.
4. Feed and delivery chutes.
5. Any supporting steelwork that may be required.
6. Any hopper work or storage bins.
7. Any motor and switchgear, or alternative drive.

The quantities and weights are then calculated and inserted in the appropriate columns, also the prices at which the raw materials and certain finished items can be purchased. Shop rates and times for other labour items, also works overheads, are furnished by a responsible official; after which the extension figures are entered in the column of costs.

Provision is made in the schedule for various items involving not material but *services*: such as drawings, carriage of material, erection expenses on the site, and provision of erection tackle; also for insurances and sundry contingencies. Erection costs vary much with local conditions and facilities, also with the men employed on the job and the weather encountered. Thus it is not easy to estimate in advance the total cost of a proposed plant, allowing for all contingencies. Erection labour alone may account for anything from 10 to 20 per cent. of the entire cost.

The priced schedule of quantities is next passed to the comptometer operator, who will rapidly check the extensions and total all the items, thus arriving at a figure representing the net production cost.

A considerable percentage must then be added to cover selling expenses, which are heavy in conveyor work, before the net cost of production is determined. In risky jobs a suitable allowance for contingencies is advisable. Finally, a small percentage is added for profit and a quotation figure decided, bearing in mind the trend of costs and the market generally.

The final stage is to type out a general and detailed specification of the job, together with a suitable explanatory covering letter, which latter may be entirely separate from the technical specification. Alternatively the entire proposal, including specification and estimate, may be covered by one document in several sheets, reference being made to the enclosed blue print or sometimes to several prints on a separate roll. The quality and character of the drawings counts; good drawings giving a favourable impression.

Instead of a single elevator an inquiry may call for a whole series of units in one installation. In an actual case over eighty separate conveyor units for a new factory were included in one contract. In such a case a flow diagram is of great utility in helping one to visualise clearly a whole series of operations or technical processes following one another in proper sequence.

General arrangement drawings showing the layout of a large number of machines are apt to be difficult to follow, especially when in the form of blue prints. Coloured white prints are much clearer, permitting of the use of systematic colour schemes and conventions.

The question of delivery is an important and difficult one. An estimated time of delivery at least is required, and sometimes a guaranteed time under a penalty for delay in completion, involving the addition of a contingency item. Before a safe time of delivery can be stated the condition of the shops and drawing office as regards work in hand, also the position as regards material in stock, and existing commitments generally have to be carefully considered. It is so easy to guess a time of delivery that cannot be fulfilled, to the annoyance and inconvenience of the purchaser. The temptation to quote impossibly quick delivery has to be resisted.

Concluding Remarks.—Government departments, corporations and some large firms find it necessary to issue lengthy documents; including specifications, general conditions, performance and data sheets and forms of tender. But the practice of other desirable purchasers of great experience is to reduce the amount of paper and form-filling to a minimum, and they certainly do not in consequence receive less prompt and efficient attention and service.

The total annual cost of preparing preliminary designs, quantities, estimates of cost and tenders that do not result in orders is a heavy charge on the conveyor industry, which causes an appreciable addition to the overhead charges on conveyor work.

Apart from municipal corporations, the buyers of conveyors are mostly large and powerful firms and combines, possessing keen purchasing departments and expert technical staffs, who know exactly what they want and mean to get it at a suitable price. Yet there are some exceptions amongst conveyor users, who have found by long experience that excellence of design, material and service are of much greater importance than low first cost in securing permanent satisfaction, and who therefore do not encourage price-cutting.

Good conveyors last a long time, the average life of one being probably not less than twenty years, perhaps five times as long as the average motor car lasts in useful service or goes out of fashion. Remembering this and the fact that the general public never buys conveyors at all, it is clear that the market is distinctly limited. So conveyors should be sold not on the basis of low price but on efficiency of performance and durability.

The demand for conveyors varies greatly from time to time. Consequently rush periods of manufacture alternate with periods of slackness. Sometimes a promise of quick delivery necessitates overtime working, and then when the material is ready for despatch at the time promised, there occurs a vexatious long pause before the site is ready to receive the plant, due to unexpected delays on the part of the building contractor. In other awkward cases, big alterations of design are asked for after the job has been half-made, necessitating scrapping part of the plant and delaying the completion of the work indefinitely.

Thus conveyor work is full of pitfalls of one kind or another, and the path of the conveyor engineer is far from being an easy one. To carry on steadily it is necessary to combine conveyor work with some other and more profitable branch of engineering, otherwise the financial results are likely to prove disappointing.

Nevertheless conveyor engineering has its compensations, it being full of technical interest to designers, on account of the large variety of plants needed to serve so great a diversity of industries. Moreover, conveyors are essential items of equipment, without which it would not be possible to maintain the required output of a factory or even to work at all on an economic basis.

APPENDIX

DENSITIES OF MATERIALS

The weights and volumes of those materials which conveyors may be called upon to handle are usually arranged in alphabetical order instead of as here progressively in order of increasing density and in groups of equal density. The former method is convenient for rapid reference but not for careful comparison of relative densities. The latter sequence from the lightest to the heaviest material is more instructive and systematic, and will also hold good in all languages, as it is not governed by names and words but by physical realities.

The figures given are approximate or average values only. The weights of certain materials vary to some extent with the size of the pieces, the closeness of packing, and the moisture content. The English long ton of 2240 pounds is used, not the American short ton of 2000 pounds. It is useful to know that a ton of wheat contains 4·66 quarters, also that there are two sacks of 240 pounds each in 1 quarter of wheat, and that a sack contains 4 bushels of 60 pounds.

Material.	Pounds per Cubic Foot.	Cubic Feet per Ton.	Cubic Inches per Pound.
Snow, freshly fallen	6	373	288
Dry hops	6·5	350	270
Cork dust	7	320	246
Dry sawdust	8	280	216
Wood meal	8·5	270	208
Bran Dry peat	11	204	157
Beet, dried pulp	14	160	125
Flaked soap	16	140	108
Ground oak bark	17	132	102
Logwood dust Flue dust	18	124	95

DENSITIES OF MATERIALS—*continued.*

Material.	Pounds per Cubic Foot.	Cubic Feet per Ton.	Cubic Inches per Pound.
Dry paper pulp	20	112	86
Green malt			
Wet sawdust			
Cotton seed	22	100	77
Town refuse (London)			
Breadcrumbs	23	97	75
Charcoal			
Locust beans			
Calcined bones			
Degreased crushed bones	25	90	69
Seedlac	27	83	64
Spent tan			
Shredded soap	28	80	61·5
Wood chips			
Damp wood pulp	30	75	58
Dry apple pulp or pumice			
Gas coke			
Malt			
Oats			
Hempseed	31	72	55
Crushed bones	35	64	49
Hydrated lime			
Soda ash			
Cotton seed	36	62	47
Rape seed			
Spent hops			
Buckwheat	37	61	46
Sugar beet	38	59	45
Coke breeze	39	58	44·5
Barley			
Hot wet grains			
Oatmeal			
Furnace coke	40	56	43
Gasworks lime			
Steamed bones			
Indian corn meal	41	55	42
Linseed			
Rye			
Bean and pea meal	43	52	40
Flour			
Turnips			
Coal nuts			
Coal ashes	44	51	39
Anthracene	45	50	38·5
Powdered coal			
Indian corn or maize			
Coarse salt			
Soda ash			

Densities of Materials—*continued.*

Material.	Pounds per Cubic Foot.	Cubic Feet per Ton.	Cubic Inches per Pound.
Sodium bicarbonate	46	49	37·7
Whole apples			
Potatoes	47	48	37
Wheat			
Horse beans	49	46	35·5
Peas and beans	50	45	34·6
Fine white sugar			
Broken ice			
Sulphate of ammonia			
Wet char			
Welsh steam coal	53	42	32·5
Anthracite coal, loose			
Quicklime			
Rye			
Bone meal	56	40	31
Block ice			
Brown sugar			
Boiler ashes			
Wet paper			
Asbestos grit	60	37	28·5
Broken glass or cullet			
Crushed dolomite (calcined)			
Pitch			
Oxide of iron			
Granulated sugar			
Wet bone char			
Sludge			
Superphosphate of lime			
Raw sugar	62	36	28
Fresh water			
Sea-water	64	35	27
Resin	66	34	26
Ground dry fireclay	70	32	24·6
Saltcake			
Bones	72	31	24
Moulding sand			
Nitrate of ammonia			
Nitrate of soda			
Chalk lumps	78	29	22
Loose earth			
Calcined limestone	80	28	21·6
Crushed chalk			
Earth			
Loose clay and marl			
Crushed slag			
Ground gypsum			
Wet fish skins			
Phosphate rock	81	27·5	21

Densities of Materials—*continued.*

Material.	Pounds per Cubic Foot.	Cubic Feet per Ton.	Cubic Inches per Pound.
Blast furnace slag	86	26	20
Crushed silica			
Mortar			
Portland cement			
Shingle	88	25·5	19·5
Broken limestone	90	25	19·3
Coprolites			
Clay shale, loose	93	24	18·5
Cement slurry	95	23·6	18·2
Dried mud			
Stone dust			
Granite chippings			
Fine sand	96	23·2	17·9
Coarse gravel	98	23	17·7
Plaster			
Cement clinker	100	22·4	17·2
Coarse pit sand			
Common bricks			
Crushed basalt			
Pit dirt			
Phosphate pebble			
Slate dust			
Wet sticky chalk			
Hard bath stone, broken	102	22	17
Plaster of Paris	106	21	16·2
Lead ore			
Gravel, average	109	20·5	16
Bauxite	110	20·4	15·7
Phosphate meal			
Wet mud			
Ballast, loose	112	20	15·4
Lime sludge			
Powdered sulphur			
Tin ore			
Asphalt, loose	120	18·7	14·5
Ground cement			
Concrete			
Gypsum, broken			
River sand			
Solid clay			
Bath stone	125	18	1·4
Solid chalk			
Solid rock sulphur			
Barytes	130	17	13
Red sandstone			
Powdered phosphate			
Derby stone, broken	136	16·5	12·7
Salt rock			

Densities of Materials—*continued.*

Material.	Pounds per Cubic Foot.	Cubic Feet per Ton.	Cubic Inches per Pound.
Plumbago Portland stone, broken Sandstone, broken Quartz, broken	140	16	12·5
Granite broken Spanish iron ore	150	15	11·5
Iron pyrites	156	14·3	10·6
Shale Zinc spelter	162	13·8	10·5
Crushed dolomite	165	13·5	10·4
Quartz sand	170	13	10·2
Lead oxide	184	12·2	9·4
Copper pyrites, fine	187	12	9·6
Iron ore, Clydesdale	190	11·8	9·5
Tin ore	200	11·2	8·2
Brown iron ore	245	9·2	7·1
Red iron ore	320	7	5·4

TABLE OF DUMPING ANGLES

The following figures give the inclination at which different materials will slide out of a tipped truck body :—

Material.	Degrees.	Material.	Degrees.
Coke	23	Dry cinders	33
Hard coal	24	Moist cinders	36
Broken stone	27	Dry sand	35
,, ,, with sand	27	Fresh ore	37
Loose earth	28	Bricks	40
Soft coal	30	Gravel	40
Crushed stone	30	Moist sand	40
Dry ore	30	Shingle	40
Concrete	30	Asphalt	45
Wet ashes	30	Clay	45
Garbage	30	Rubble	45
Dry ashes	33	Compact earth	50

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1913. W. H. Atherton addressed the Manchester Association of Engineers on "Package Conveyors for Factories."

1913. R. B. Creak addressed the Institution of Mechanical Engineers on "Modern Flour Milling Machinery."

1916. James Tinto addressed the Manchester Association of Engineers on "Indiarubber and Balata Belting as Conveyor and Power Transmission Belts."

1916. W. H. Atherton addressed the Institution of Engineers and Shipbuilders in Scotland, at Glasgow, on "Chain Belt Conveyors."

1917. W. H. Atherton contributed to *The Electrician* for December an article on "Conveyors and Elevators."

1918. W. H. Atherton addressed the Manchester Association of Engineers on "Conveyors in Relation to Engineering Works."

1918. W. H. Atherton contributed to *Cassier's Engineering Monthly* a series of articles on " Conveyors for Chemical Works."

1919. W. H. Atherton contributed to *The Electrician* for January an article on " Some Details of Conveyors and Elevators."

1921. W. H. Atherton addressed the London Association of Foreman Engineers on " Elevating and Conveying Machinery."

1921. H. J. Smith addressed the Institution of Mechanical Engineers on " The Mechanical Loading of Ships."

1921. G. Mitchell addressed that Institution on " Conveying and Elevating Machinery."

1923. D. Fife addressed that Institution on " Modern Dock Appliances at Glasgow Harbour."

1924. W. H. Atherton addressed the Leicester Association of Engineers on " Conveyor Chains and their Applications."

1925. W. H. Atherton contributed to Cassier's Mechanical Handling Number an article on " Malleable-iron Conveyor Chains and their Manufacture."

1927. W. H. Atherton addressed the Institution of Mechanical Engineers, at Leeds, on " Modern Conveying Machinery."

1930. G. E. France addressed the Institute of British Foundrymen, at Manchester, on " The Foundry is a Machine."

1930. T. E. Dimbleby addressed the Society of Glass Technology on " The Mechanical Handling of Raw and Manufactured Material in Glass Works."

1930. W. H. Atherton contributed to *Cassier's Mechanical Handling* an article on " The Discharge of Bucket Elevators."

1931. W. H. Atherton addressed the Institution of Mechanical Engineers, at Glasgow, on " Continuous Elevators."

1931. W. L. Beeby addressed that Institution on " Handling of Materials in a Mass-production Factory."

1931. W. L. Hartley contributed to *Cassier's Mechanical Handling* an article on " Mechanical Handling of Moulds in Foundries."

1932. W. H. Atherton contributed to *Iron and Steel Industry* an article on " Conveyors in Relation to the Foundry Industry."

1933. H. H. Broughton addressed the Institution of Mechanical Engineers on " Handling and Storing of Grain."

1934. F. M. Birks addressed that Institution on " Gasworks Practice."

1934. D. E. Cameron addressed the Institute of Fuel on " Coal Handling at Ports."

1936. W. H. Atherton addressed the Managers and Overlookers' Association, at Bolton, on " Conveyors with Special Reference to the Textile Industry."

1936. F. Gudgeon addressed the Derby Society of Engineers on " Recent Foundry Developments and Continuous Moulding."

1936. E. Longden contributed to *The Engineer* (11th December) an article on " Mechanisation of Foundry Operations."

INDEX