The subject of this paper is the mechanical handling of materials by fixed or portable equipments of the type generally used in our secondary industries, public, or construction works. The nature of the work performed by this class of machinery, and the conditions obtaining at the site of installation, vary so greatly that it is evident that no two equipments are exactly alike. This, like all other branches of engineering, involves special knowledge of the principles of design of these plants, and the application of an extensive experience in their operation, in order to supply the purchaser with the most suitable plant, and one which will give long and satisfactory service. The author endeavours to give a broad outline of the fundamental principles of design and operation, and special points of interest connected with installations with which he has been connected.

The paper is arranged under four sections:—Machines which lift material—elevators; machines which carry material—conveyors; machines to lift and carry—carriers; and aerial cable ways and similar installations.

**Bucket Elevators:** When raising free-running material not heavier than 80 lbs. per cubic foot, the material may be discharged over the top by centrifugal force. Generally the requisite speed is 200 feet per minute; but the speed is calculable from the equilibrium of centrifugal and gravitational accelerations. In practice it is generally convenient for discharge to commence at 45 degrees from the vertical.

**In Positive Discharge Elevators** idler sprockets are located under the head shaft, so that the chair is drawn in towards the centre line of the elevator, thus inverting the bucket and permitting a positive gravity discharge. This type of elevator is used where low impact at the point of pick up necessitates low speeds or for wet, sticky material. The boot, where the material is picked up, is of the same general design in the two types of elevator. The foot sprockets or drums are usually .75 to .5 the diameter of the head sprocket; if too small, centrifugal force would preclude loading below the level of the foot shaft.

**Continuous Bucket Elevators** have V-shaped buckets, so that the discharge, pouring over the bucket beneath, is deflected outwards. Speeds are adjusted to be just sufficient to dislodge material centrifugally, and prevent it falling be-
tween the buckets. Loading is effected by chute and skirts above the level of the foot shaft. In all elevators the ratio of diameters of head pulley and foot pulley is 2:1 for grain, flour, bran and chaff, and 4:3 for pulverised cement and lime, and ashes, coal, coke, gravel, stone, etc., where 2-inch cubes do not exceed 10 per cent. of the mass. The bucket capacity is usually allowed at 75 to 80 per cent. of its level-full capacity. The bucket minimum spacing must preclude material of one bucket striking the adjacent bucket. When digging material, only half the above effective capacity is realised. Inclined elevators may be worked at 25 or 30 degrees if fitted with suitable buckets. Electrical tests on motors show that bucket elevators are only about 50 per cent. efficient in power. Allowance must also be made for power lost at the dumper. Other elevators include swing-tray, wool bale, bag, etc.

*Belt Conveyors:* Generally the minimum width allowed is four times the average size of material handled where such pieces are 70 per cent. to 80 per cent. of the total material; or twice the size of the largest lump plus 8 inches where such pieces do not exceed 10 per cent. of the whole. The maximum permissible speeds vary from 300 feet per minute on 14-inch belts to 600 on 48-inch belts. Speed also depends on the class of material handled, e.g., oats 600, wheat and barley 550, maize, beans and heavier seeds 800 feet per minute, while lump materials are limited to 150-250 f.p.m.

The present tendency is to use wide, shallow belts with simple idlers. Duck for rubber belts is graded in 20, 28 and 36 oz. per piece 42 in. by 36 in. The warp (lengthwise) threads are usually larger and closer together than the weft threads, and the size of the thread is determined by the number of spun yarns per thread. Thus one weave of 28 oz. duck may have 6 yarns of 26 threads per inch in the warp and 5 of 17 in the weft, while another weave of same weight may have 6 x 24 in warp and 5 x 14 in the weft, but with a tighter twist in the thread to make the weight. The strength of the duck depends not only on its weight, but also on the twist of the thread. Successive layers of duck are cemented together with "friction," and the value of this adhesive depends on the quality of rubber and openness of the weave of the duck. The rubber cover on the carrying side is generally: 3/128 inch for grain, sugar, corn, clay and sawdust; 1/16 inch for cement, sand and small coal; while for heavier materials it varies from one-eighth to three-sixteenths inch. Under sand blast tests the comparative resistances to erosion are: Rubber 100, rolled mild steel 66½, cast iron 28, and various cotton belts 11 to 20. As an example of life of rubber belts may be cited a 15 in. 5-ply belt used in a local quarry, which in four years carried 116,281 tons of crushed
stone with a large proportion of 3\text{\frac{3}{4}}\text{ inch} cubes. It carried an average of 30,000 tons per annum, and was estimated to have at least another two years of life, or 176,000 tons in all. Another 12\text{-inch by 5-ply} belt had a seven years’ life, and transported 75,000 tons. The probable life of a belt has been expressed in tons equal to 500 times the square of the width in inches for every 100 feet length between terminals.

Special heat-resisting belts are now made for temperatures as high as 200 degrees C. Acid-resisting belts are also made. These have the same life as belts for ordinary material.

The horse power required to drive a belt conveyor depends on many factors. For horizontal transport, using greased idlers, one prominent firm uses the formula:

$$H.P. = \frac{(CS + 2.60T) L}{33,000} + \frac{TH}{884}$$

Where $S$ is the speed of belt in feet per minute, $T$ is the load in tons per hour, $L$ is length of conveyor between centres, $H$ is vertical height of lift, and $C$ is a constant with values given below:

<table>
<thead>
<tr>
<th>Width</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>24</th>
<th>30</th>
<th>36</th>
<th>42</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C$</td>
<td>0.75</td>
<td>1.05</td>
<td>1.35</td>
<td>1.70</td>
<td>2.00</td>
<td>2.45</td>
<td>3.55</td>
<td>4.15</td>
<td>4.75</td>
</tr>
</tbody>
</table>

An additional allowance must be made for energy lost at the tripper, and for efficiency of gearing at the driving end.

Safe maximum working tensions are allowed at 30 lbs. per inch width per ply. This gives a factor of safety of 12.

To ensure against slip on the driving pulley the ordinary computations for belting must be followed, using a co-efficient of friction of 0.25 on cast iron and 0.35 on lagged pulleys. The present tendency is to install roller or ball bearing idlers. The advantages are: Lower initial cost of belting and motors, lower operating cost of power and lubricant, and lower maintenance. There is a saving of about 20 per cent. in power on conveyors 200 feet between centres, and 40 per cent. on conveyors up to 600 feet long. The life of these bearings has been matters for experiment by the makers, and it seems that they are as long-lived as plain bearings, and require far less attention.

The spacing of troughing idlers depends on the weight of belt and load. Excessive sag causes rubber friction, and attrition on the upper surface, thus shortening the life of the belt.

The diameter of the head pulley should not be so small as to over stress the belt carried over it. Magnetic head pulleys are usually provided when the material is fed into crushing,
grinding or pulverising plants in order to separate and remove ferrous material and thus protect the grinding plant. About 400 watts of direct current for a pulley 12 in. diameter by 16 in. face, and 4100 watts for a 30 by 60 inch pulley, are required.

*Automatic Weighers* can be installed to weigh and record the material being conveyed on belt or pan conveyors or carriers. In belt conveyors, where the weight per foot of the belt is constant, a guaranteed accuracy of 99 per cent. is obtainable without hindering in any way the transport. This standard of accuracy is slightly less with pan conveyors or carriers, owing to the variation in the weight of compound parts.

The general construction of these weighers provides for a section of the conveyor belt and idlers to be supported on a floating platform, which is hung on compound levers and balanced by an iron float in a cylinder of mercury. This section has usually a length in feet equal to the speed of the conveyor in feet per minute divided by 12.

The movement of the float is a direct measure of the weight on the conveyor belt. An integrator multiplies this weight by the speed of the belt, and records the tonnage passed over, this integrator being driven by a chain drive from snub drums fitted to the return strand of the belt.

One type of automatic weigher will also make a deduction for any material which may stick to the conveyor belt and be carried round on the return side.

*Brief reference is made in the paper to spiral conveyors, apron and canvas pocket conveyors, and to special types for transporting bottles slowly through lehrs.*

A newspaper conveyor and elevator recently installed in the "Herald" office was shown on the screen. It was developed to accept newspapers as they are printed. One section is connected to and driven from the press; the papers are held between special wires tensioned by rollers so that the papers overlap by a definite amount, and the count of them is maintained. Two speeds are provided to enable the same lap to be maintained when the press is running full speed or less. A separate motor enables the conveyor to clear after the press has stopped.

In *V-Bucket Carriers* the buckets are fixed rigidly between two strands of chain; and troughing is provided on the horizontal sections so that the buckets here act as scrapers. The discharge is effected through gates at any point in the trough. The carrier is suitable for handling coal, as several
installations in Australia testify; but great wear and deformation would follow its use on hot, gritty material like coke. These carriers are not economical for handling less than 20 tons of coal per hour. The buckets for this capacity are usually about 16 in. long by 14 in. wide and 7 in. deep, spaced 24 in. centres. The economic maximum is about 100 tons per hour, using bucket 30 in. long by 24 in. by 7 in., spaced 36 in. apart, largest lump being 12 in. cube. The bucket speed is usually about 100 feet per minute.

In calculating the power necessary, it is usual to allow a coefficient of friction of about 0.35 for the mass in the trough section for chain with machined rollers.

_Pivoted Bucket Carriers_ have been developed to meet the extremes of conveying requirements. It is the only type to successfully handle hot, gritty materials—both to elevate and convey. They can convey on both upper and lower strands and elevate at any angle. In the “contact” lip type the bucket is free to turn a complete revolution at any point. This type requires a rotary-feeding device. In the more recent “overlapping-lip” conveyor, however, the feeding device may often be dispensed with, but a lap-changing device must be fitted to the top sprocket where the chain begins to descend. This precludes its use for handling coal, coke and ashes on the one conveyor, because it cannot carry on the descending leg. Owing to the high initial cost carriers of this type are not economical under 50 tons per hour, for which capacity the buckets would be 18 in. wide by 24 in. long. Capacity of 150 tons per hour, using buckets 36 in. wide by 30 in. long, is about the utmost economical limit. The bucket speed is usually 50 ft. per minute. Owing to the long-pitched chains being used on sprockets with a small number of teeth, a pulsating motion is imparted to the chain, and various appliances involving cam and pawl drive are described in the paper.

_Aerial Cable Ways_ are installations where only two towers or masts are used for operating one carrier only. Both towers may be movable, or one or both fixed. When fixed they may be luffed to right or left, which slightly increases their effective range. The ropes used comprise the main carrying, hoisting, travelling and button ropes; the last of these is to keep the former from interfering with each other by a number of fall rope carriers, and to greatly increase the permissible working speed. This is accomplished by attaching buttons of successively increasing diameter at regular intervals on its length. The cable way carrier is provided with a horn which accommodates a number of fall rope carriers, located on the rear of the carriage, each having a head.
to correspond with a button; consequently, as the carrier travels out, it leaves fall rope carriers at definite places and collects them on the return journey.

Travelling speeds up to 600 f.p.m. can be obtained without undue maintenance using rigid head fall rope carriers. But speeds of 1500 f.p.m. can be obtained by using special slotted head carriers, designed to overcome impact. Hoisting speed may be as high as 300 f.p.m. Standard methods of calculating the sag, strength of rope, and power were given in the paper.

Rope Haulage of trucks by continuous or counter-balanced systems were briefly dealt with. In continuous rope haulages provision must be made for the extension and contraction of the rope due to varying loads thereon.

Aerial Rope Ways in many cases are the only means for economically handling bulk materials, and on account of their small cost, independence of obstacles, or ground formation, or climate, their simplicity of working, and small running and maintenance expenses. The ground over which they pass entails only a small outlay for rent or purchase. Power developed by descending loads can be used for returning or pulling up empty buckets, and when in excess of this can be used for driving other machinery. The original cost of the installation is often recovered in a year by the saving in transport. The average cost per ton is threepence from one to four miles. Rope ways can be made practically automatic. There are two types: Mono-cable and Bi-cable.

The Mono-cable used one continuous rope for both carrying and hauling. Long haulages may be broken into sections, and the transfer from one section to the next is accomplished by rails at intermediate stations. A flexible rope is requisite such as a Lang or Albert lay.

A Bi-cable comprises a fixed carrier rope and a haulage rope. The former are usually full-locked or half-locked cables, so as to present a smooth surface for the carrying wheels. The haulage rope is usually 6/7 construction Lang's lay, as it is essential that reasonably large wires be used to resist wear due to the operation of the grips, and still have sufficient flexibility to pass around the driving sheaves.

Opinions regarding the relative merits of mono-cable and bi-cable ways differ. Continental and American opinions favour the bi-cable, while British engineers favour the mono-cable. The mono-cable has lower capital cost, and as the rope always passes a fixed point, it can be inspected at any period of operation. But its ropes require frequent renewal, and the wear on the pulleys is excessive. The capacity of the line
MECHANICAL HANDLING OF MATERIALS.

cannot be increased without large expenditure; whereas in the bi-cable a heavier rope may be installed on the loaded side, while the old carrier rope may be used to replace the original lighter return rope. In mono-cable ways carriers and buckets are liable to sway in a high wind and spill material or fall from the line. If the rope should break the whole line comes down, whereas in bi-cables one rope is usually able temporarily to support the line.

Bi-cable ways involve lower maintenance and require lower power to drive them. Carriers can negotiate curve, tension or summit stations, and returning pulleys in unloading stations without being detached from the hauling rope. The capital cost is higher than for mono-cable ways, but still the plant is more economical.

Rope ways are suitable for capacities anywhere between 5 and 500 tons per hour. For small tonnages over distances up to 1000 feet a reversible rope way, either mono-cable or bi-cable, is occasionally used. The maximum length of one section of aerial rope way is five miles; this, of course, necessitates 10 miles of moving rope. If longer, the line must be divided into sections with intermediate stations. A number of rope ways, each having a total length of over forty miles, is in operation in various parts of the world. The load per bucket varies from 500 lbs. in 5 ton per hour lines to 3000 lbs. in 500 tons per hour lines. Logs up to 30 ft. long and weighing 3 tons can be carried, but only on bi-cable ways. Spans of 5000 feet are not uncommon in crossing gullies or ravines where there is sufficient height for the sag or the rope without the buckets touching the ground. Shorter spans are necessary on hill crests. Tension stations or rail passages are provided; the carrying ropes are carried through the station, but rails are mounted above them to intercept the carrier without it being detached from the hauling ropes, thus reducing the wear on the hauling rope. The distance between carriers should not be less than 150 feet. The usual speed is 8½ feet per second on a straight line, but where automatic curve stations or tipping is required it should not exceed 6½ feet per second. The author demonstrated the mode of calculation of requisite driving power. The friction of the terminal machinery is about 10 per cent. of its weight, and an additional amount of power is necessary to overcome starting inertia; an allowance of 25 per cent. will cover this.

The paper was profusely illustrated with slides of numerous installations in Australia with which the author had been connected.
The President said all were grateful to Mr. Cameron for his very able paper covering all the branches of mechanical handling of materials. All engineers were interested in the subject; and since the paper was so comprehensive he would suggest that discussion be deferred until the paper had been printed.

Mr. J. T. N. Anderson moved a very hearty vote of thanks to Mr. Cameron. It was some years since the Institute had received such a comprehensive paper. He hoped all members would do it justice when it was printed.

Mr. W. R. Pollock seconded the motion, which was carried with acclamation.

COMMONWEALTH ENGINEERING STANDARDS.

Mr. Edward Bartlett, Assistant General Secretary of the Australian Commonwealth Engineering Standards Association, gave a brief address urging members to support the very valuable work of the Association, and to recommend the respective firms with which they were connected to adopt the Association's standards in their specifications.

A vote of thanks to Mr. Bartlett for his inspiring address was carried with acclamation.

At 10.45 the meeting closed.
Mr. W. H. CUMMING exhibited several parts of conveyors as used in the Metropolitan Gas Co.'s works. The first exhibit was a pair of links as used for either tray or bucket conveyors. The individual pieces forming the links were stamped in a hydraulic press from ordinary flat mild steel bar; the holes were punched and countersunk and pins rivetted in. In the company's plant there were about 6000 of those links in fairly constant operation. In order to minimise wear they had case-hardened the links where they moved on the pins. The total weight of chain and tray conveyor was about 85 lbs. to the foot run of conveyor. The trays were stamped from 3/16 in. mild steel. Strips 17 inches wide were cut off; these were fed into a die that at one movement cut off the requisite length, pressed in stiffening ribs, and bent the tray to form. Then the press came forward again and stamped holes for the square-headed bolts. He also exhibited some much heavier links used on a coal elevator which had something like 130 feet of vertical run, and 135 feet horizontal run, and it had removed about 200,000 tons of coal. The links had been reinforced at the wearing points with manganese steel welded on. A cut was taken out of the inside of the eye, and was afterwards filled with the manganese steel. The mild steel pin was case hardened. It was locked in place by a split ring. A conveyor bucket was also exhibited that, instead of being stamped out, was entirely welded up out of three plates—the two end plates and a single plate going round the bottom.

Mr. A. E. HUGHES said that not the least interesting portion of Mr. Cameron's paper was the fact that any practitioner could work to it with the assurance that he would get definite results. He considered Mr. Cameron was conservative in his claims of capacities and speeds. Possibly his object had been not to include anything in the paper that could not be substantiated. On the whole the paper covered the field so widely, and so few practitioners had the opportunity of gaining experience in all lines, that it really resolved itself into a very useful text book.

He had missed the grasshopper conveyor of sheet metal hung with links or flat steel bars. They had a high capacity with very low power consumption. Maintenance costs were
extremely low. It was wonderful the amount of material that could be carried along those conveyors with such small power. They were largely used for conveying sand, sawdust, rice and wheat. For articles that carried no moisture content they were better than the band, because there was no throwback.

Mr. Wm. CHAS. ROWE thanked Mr. Cameron for his paper. It seemed to him that the grasshopper conveyor was not generally known. He had heard it spoken of as the Zimmer conveyor. It was a very interesting subject, because it was subject to several laws, which, if brought into unison one with the other, gave the best results, results which could not be obtained otherwise.

Mr. C. BAILEY said he had had some experience of the Zimmer conveyor, which was largely used for the handling of wheat, coal and water.

Mr. A. C. CAMERON, in reply, said he greatly appreciated the reception of his paper. He had tried to present something of use, and hoped he had succeeded. He was much interested in the examples exhibited by Mr. Cumming. They contained engineering features that were unique, e.g., the insertion of manganese steel. In that class of conveyor trouble was usually met with in connection with the chains. He had found that those conveyors required very careful lubrication. With reference to the remarks of Mr. Hughes, he certainly felt it was a big task to cover the full range of the subject, and had confined himself to those generally in use. There were others worth considering, but he thought the time would be better spent in considering those of most interest to members.
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