HOISTING MACHINERY

W. H. ATHERTON

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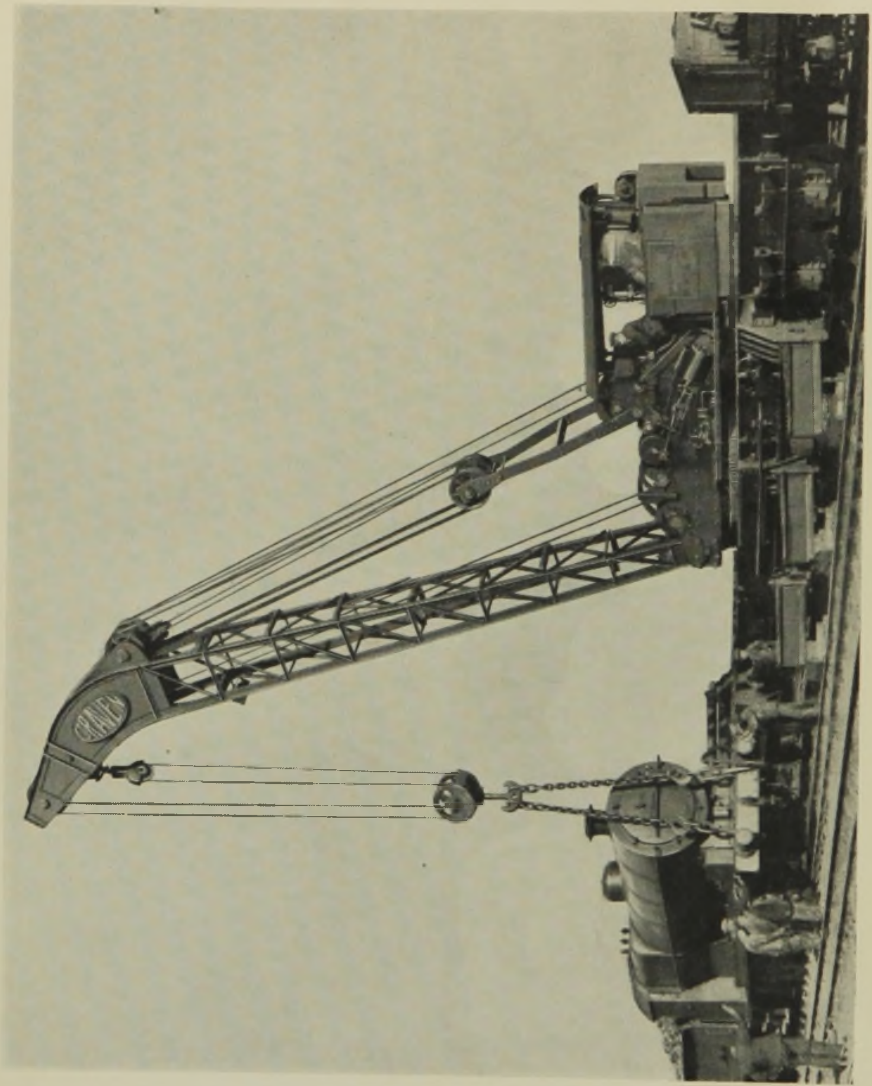

Craven Bros. Crane Division Ltd., Loughborough.

A Big Steam Breakdown Crane in Action.

Frontispiece.]

HOISTING MACHINERY

Comprising

CRANES, DERRICKS, GRABS, SKIP HOISTS,
STACKERS, TELPHERS AND TRANSPORTERS

BY

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Member of the Institution of Mechanical Engineers
Author of "Conveying Machinery"

WITH NUMEROUS ILLUSTRATIONS,
GRAPHS AND PLATES

55

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PREFACE

In my book on " Conveying Machinery " I have dealt solely with the handling of materials, goods and packages in a *continuous* stream ; whereas the present work is devoted exclusively to the *intermittent* short-range movement of goods of all kinds, whether isolated heavy objects or parcels in containers, or grab loads of loose materials such as coal and coke.

The characteristic feature of a conveyor is an endless belt of some kind, moving steadily round a drum or a wheel ; whereas that of a crane is a hook or a hoist-block supported by a rope or by a chain winding on or off a drum at intervals. The one operates continuously and the other intermittently.

Cranes and conveyors are often used in conjunction and complementary, the one feeding the other. For some duties they are alternative and competing appliances, as in filling an overhead storage hopper with coal, an operation that can be done either by means of an inclined belt conveyor or by a vertical bucket elevator or by a skip hoist or a high-level jib crane or, again, by an electric telpher equipped with a grab.

Cranes are probably of more general interest and utility than conveyors, and they are certainly more exposed to the public gaze. Conveyors are seldom in evidence save inside of specialized factories of various kinds ; whereas some types of cranes are very prominent features of the skyline, especially in the vicinity of railway stations and docks where heavy goods have to be transhipped.

Cranes are also often seen in operation by the general public in places where bulk material has to be moved and loaded up, as when extensive civil engineering works are in progress. To large-scale public works contractors and other big users, however, cranes are much more than of general interest, for they are essential tools or plant without whose valuable aid effective progress would be impossible.

The long-range transport of goods or freight is the function of motor vehicles and railway trains on land, of canal boats or barges and ships on water and of airships and aeroplanes in the air ; yet railway, dock and shipping companies are large users of cranes (mainly of jib types) for loading and unloading operations at goods terminals.

Moreover, all the heavy industries utilize cranes in their workshops, where overhead travellers are generally preferred for internal lifting operations, though shipbuilders use derrick and tower cranes on a big scale. Thus the various applications of cranes are very numerous, both for inside and outside duties, whilst relatively small modifications in the design of jib cranes convert them into mechanical shovels and excavators.

Joseph Horner, of Bath, who died in 1927 at the advanced age of eighty, had a long experience in the actual work of crane construction, a branch of mechanical engineering in which he became an undoubted authority. Hence the distinctly practical and 'shoppy' character of his writings. Early in this century he wrote a small book on "Hoisting Machinery," which the publishers have invited me to revise, and so the substance of this is included in the present volume. But the matter of Horner's original book has been so greatly pruned, rearranged, amplified and modernized as to form an almost entirely new work. Indeed, the text has been completely rewritten and many new illustrations introduced, whilst the more scientific aspects of crane designing have not been overlooked.

The study of hoisting machinery forms an excellent basis on which to build up a knowledge of other branches of mechanical engineering, for machinery details of almost every kind are represented in cranes, as well as structural elements like jibs and girders. Several types of prime movers and modes of power transmission are also utilized for driving them. Hence this book may be profitably read by any young engineer desirous of studying the methods and processes of machine designing and of learning how to apply the general principles of mechanics to actual machine construction.

The subject has been dealt with mainly from the standpoint of the drawing-office and the works rather than from an academic point of view, the fruits of much practical experience having been embodied in this volume. It should prove of special interest and service to those engaged in the design, the construction, the application and the maintenance of cranes and other hoisting machinery. I have been at some pains to make the book readable and not too academic.

Apart from those primarily interested in the technology of cranes from a professional standpoint, there are some *amateur* mechanics both young and old, I hope, who will find this book helpful and stimulating. Many folk besides engineers love making *models* purely as a hobby. To some of these an adaptable machine like a locomotive jib crane may be recommended with confidence as a particularly good subject for a model, forming a pleasing variation from the ultra-popular locomotive engine.

At the London "Model Engineer Exhibition" of September 1938, amongst the crowd of *engine* models exhibited there were only two model *cranes*, one of these being a steam locomotive travelling crane and the other a lifting, luffing and slewing hydraulic crane. The finest model of a crane that I have seen anywhere is the steam breakdown crane shown under a glass case in the entrance hall of Euston Station, London. It is a very high-class job both in design and in workmanship. This exhibit should prove a real stimulus to any ambitious mechanical model maker who has the opportunity of studying it.

A modern locomotive breakdown crane is much superior in versatility to an ordinary locomotive, for the latter can do only *one* thing, whereas a crane can do *several* things. It can hoist up a load, luff or derrick the jib, slew round or rotate with its load, travel along rails and deposit its load in another place. Moreover, such a crane not only has an engine and boiler but it also possesses a lot of gearing and mechanism controlling the hoisting, travelling and other motions.

Consequently the study and building of a model locomotive crane should prove even more interesting and instructive than the building of a model locomotive, however delightful that might be. So this book about cranes will, I trust, have a wide appeal to amateur mechanics and model enthusiasts as well as to professional engineers.

In my efforts to become a guide, philosopher and friend to the younger generation of engineers I have directed attention both in the text and in the bibliography to numerous sources of information where various aspects of hoisting machinery are more fully discussed and developed than has been found possible within the limits of this book.

Many years ago an eminent crane specialist, when addressing an American audience at Cleveland, Ohio, made this rather surprising comparison: "The building of cranes has long been recognized in Europe as one of the most important subjects in the field of mechanical engineering, and cranes of many forms are there seen applied to an almost infinite variety of uses. In America, on the contrary, cranes are but little used or appreciated ; in comparison, at least, with the extent of their application in European countries. It is the purpose of this paper to present to American readers a brief classification and description of the most important types of cranes, and a similarly brief study of the more important elements entering into their construction. With a better knowledge of crane construction will surely come a better appreciation of their economy and value as labor-saving machines. In hundreds of mills and workshops heavy material is now being moved and handled by manual labor at an expense so much in excess of the cost of doing the same work far more rapidly and conveniently by crane, that the saving effected by the latter would yield an annual profit of from twenty to fifty per cent. upon their first cost, while in many cases this outlay would be entirely repaid by the economy of one year's use."

That interesting passage occurs in Henry R. Towne's paper on "Cranes," read before the American Society of Mechanical Engineers in 1883 ; that rather distant year when my own apprenticeship to engineering began in Manchester.

I wonder how far Towne's criticism is true to-day ! Surely one can now safely say that American crane practice is fully equal to that of any European country, while there is certainly no lack of appreciation of the economic value of labour-aiding machinery in the United States of America.

Apart from the abundance of line drawings included in my text, the marked courtesy of several well-known firms (see page 307) has happily enabled me to present, in numerous half-tone plates, many examples of modern crane practice, both British and American, which will greatly assist in elucidating and supplementing the text proper. For the most part the offices and workshops of these very helpful firms have been visited and the examples carefully chosen by me personally. I hope the illustrations will be studied and appreciated by anyone who may have to design or build, buy or sell, or to use and understand hoisting machinery.

W. H. ATHERTON.

DERBY, ENGLAND.

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HOISTING MACHINERY

CHAPTER I

INTRODUCTORY AND TERMINOLOGY

Classification and Nomenclature of Cranes.—The earliest forms of cranes were jib cranes and were probably so called because of their fancied general likeness to a large wading bird with long legs, neck and bill. But many designs of cranes have now departed very widely from the earlier forms. There is certainly no resemblance between an overhead traveller and a bird.

The variety of cranes is so great that it is not easy to classify them systematically. One may compare them with the instruments of an orchestra, which are broadly grouped into the three great divisions of Bowed, Wind and Percussion, according to the manner in which energy is applied to produce the vibrations of sound, though all alike are man-power instruments. It is only when we come to the pipe organ that hand power is often displaced by either a water motor or an electric motor.

In the case of cranes, however, every possible source of energy has been applied to drive them. The earliest cranes were all hand operated. Then came steam, high-pressure water, compressed air, electricity, and finally petrol or even crude oil in Diesel-engine driven cranes. Ropes, chains, shafts and gears have all been used as transmission media. Thus we might classify cranes broadly into hand cranes, hydraulic, pneumatic, electric cranes and so on, quite apart from the general design and the arrangement of details.

Some cranes are tied to one spot and so are known as *fixed* cranes. Others can go almost anywhere, having unlimited mobility. Some are mounted on wheels adapted for smooth rails, like a locomotive crane. Others have chain tracks like caterpillar or crawler cranes, suitable for travelling over rough ground. There are also *floating* cranes, for occasional use in rivers and docks and harbours. Thus on the *mobility* basis of classification we have (1) Fixed, (2) Revolving, (3) Portable, (4) Walking, (5) Travelling, (6) Floating, (7) Locomotive and (8) Mobile cranes.

Again, cranes of various classes may be identified by their conventional names as (1) Derrick, (2) Jib, (3) Overhead traveller, (4) Portal, (5) Pedestal, (6) Goliath, (7) Titan, (8) Hammer-head, (9) Transporter, (10) Caterpillar, (11) Mobile or versatile crane and so on.

Lastly, cranes may also be classified according to their *function* and *location* into (1) Coaling, (2) Foundry, (3) Wharf, (4) Breakdown, (5) Quarry, (6) Block-setting and other cranes.

The design and construction of heavy cranes is a branch of mechanical engineering needing much technical knowledge and commercial experience for its successful prosecution. The variety of types and range of sizes are so great that no one firm is expected or prepared to make every kind of crane, specialization being necessary to secure technical and financial success. Some firms specialize in jib cranes and others in overhead travellers. Some, again, concentrate on light cranes and others on heavy cranes. The choice depends on the technical qualifications of the staff, the nature of the shop equipment, and the previous accumulated experience and connections of the particular firm.

The *reputation* of an engineering firm for a particular product is a powerful factor in the securing of contracts for the construction of hoisting machinery. The buyer must have full confidence in the ability and stability of the firm to carry out its obligations and undertakings faithfully and well, especially as regards special cranes of exceptional magnitude. Price, design, workmanship and time needed for the completion of the contract are other important practical considerations. But as regards the smaller standard everyday cranes made in quantities, these have become mainly a manufacturing proposition, to be produced as cheaply and as quickly as possible for sale in a highly competitive market.

Value of Experience.—Cranes do not wear out quickly, as they are not in constant operation. There are some cranes still in use that were made perhaps fifty years ago. Hence some of the remarks written by Joseph Horner long ago from his own experience still remain true and applicable to-day.

In no structures built by engineers is the due relation of strength to stress of greater importance than in cranes, and in few is the accumulated experience of success and failure of greater value; a fact that has notable parallels in the development of locomotives and of machine tools.

There are certain crane details in regard to the strength of which calculations are of much value, because the stresses are readily obtainable, either by calculation or by the methods of graphic statics. Yet the proportions of main side-frame castings, and indeed of castings generally, are not readily calculated, but are usually copied or modified from previous designs that have stood successful service.

It used to be said, and it is still partly true, that in the drawing offices of crane shops new designs are got out without much direct calculation, because previous practice is drawn upon. The more highly the work of a firm is specialized, the more easily can modified designs be produced. Yet there is a lot of satisfaction to be obtained from calculating whatever is feasible, for it gives such a feeling of security.

Moreover it is often possible to take certain trains of gears, also barrels which have been previously used, and transfer them *en bloc* to other cranes that vary in details of design. Jibs are standardized for different radii and lifting capacity, as also trucks, posts and wheels. In fact there are standard superstructures which can be taken bodily and put on either portable or fixed bases. Lastly, standard cranes can be made in a wide range of sizes and kept in stock for prompt delivery.

Safety Precautions.—Though the stresses in certain crane elements can be obtained with sufficient accuracy there nevertheless remain some details where the stresses due to working are indeterminate. For cranes are subjected not merely to static loads but also to live and impulsive loads or severe shocks, as when a falling load is arrested too suddenly. There is no single detail of a crane which has not failed under accidental stress, hence the large factors of safety adopted in crane work.

These accidents happen not always by reason of want of sufficient strength such as is fairly warranted by past experience, but they are due to the fact that duties of too severe a character are carelessly imposed on cranes. In short they are overloaded. To prevent accidents modern cranes are fitted with safe load indicators.[1]

Hence experience must be the controlling guide, though calculations of stresses and scantlings should always be made where possible (especially when preparing new designs) by applying systematically the sure principles of applied mechanics.

In crane framings we have perfect applications of the triangle of forces, in which, knowing the nature and direction and magnitude of one force, the others can be measured off graphically. In the travellers and similar cranes we have a simple case of beams supported at both ends and loaded at intermediate points. In balance cranes the moment of the load, due to the overhang of the jib, has to be counterbalanced by a load of equal moment behind.

In the case of portable cranes the conditions of *stability* include the equilibrium of the truck, in addition to the balancing and stability of the superstructure. In one way this is governed by the length of the truck's wheel-base and in the other direction by the gauge of the rails, or by extraneous supports, as by rail clips or by blocking girders.

In some crane elements (as tie rods, chains and ropes) the pull is direct and easily reckoned ; in other details (as ground wheels, roller paths and roller rims) the load is purely compressive ; while in yet others (as posts, drums and gears) it is partly compressive, partly shearing and partly bending. Girders and truck frames are subjected to combined bending and shearing forces, while shafts are designed to withstand combined bending and twisting moments. Some calculations regarding the strength of details will be found in later chapters.

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[1] In this connection two Home Office Safety Pamphlets may be read with advantage, viz. No. 3 on " The Use of Chains and Other Lifting Gear " and No. 15 on " The Use of Derrick Cranes." At the Home Office Industrial Museum, Westminster, may be seen the Wylie, the Vickers-Nash and several other types of safe-load indicators, designed to meet the requirements of the factory acts for the prevention of accidents.

CHAPTER II

SIMPLE TYPES OF CRANES

In cranes of the simplest types the elementary frame is a triangle composed of post, jib or boom, and tie. This frame is embodied in both fixed and portable cranes of the wall, the derrick and the wharf types, including cranes whose jibs are either curved or cranked to clear bulk loads beneath.

Perhaps the simplest form of all is the smithy crane (Fig. 1), where a single tie-rod supports a horizontal track for the run of the *pulley-blocks* between a smith's hearth and the anvil, the whole being carried by either a wall or a steel stanchion, to which it is pivoted. The pulley-block is slung from a light trolley (Fig. 2) which is traversed by hauling on the block chain.

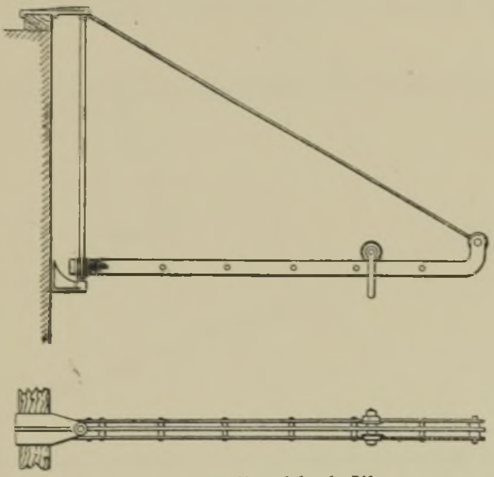

Fig. 1.—Pulley-block Jib.

A development of this simple hand crane is shown in Fig. 3, where the direct-acting *air cylinder* replaces the pulley-blocks and is drawn along the jib track by a hanging hand chain actuating the track wheels of the trolley through spur gears. The air cylinder swings in trunnions, while the entire crane is pivoted to brackets bolted to the shop wall. The lift is limited in extent by the stroke of the piston inside the cylinder.

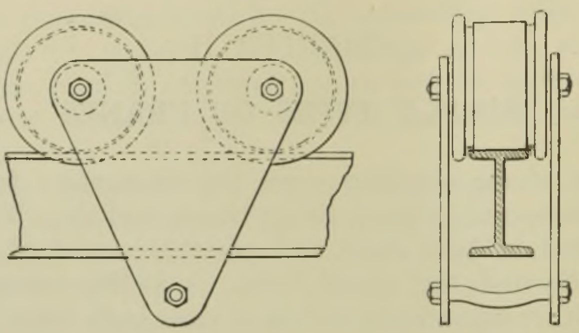

FIG. 2.—Trolley or Jenny for Pulley-block.

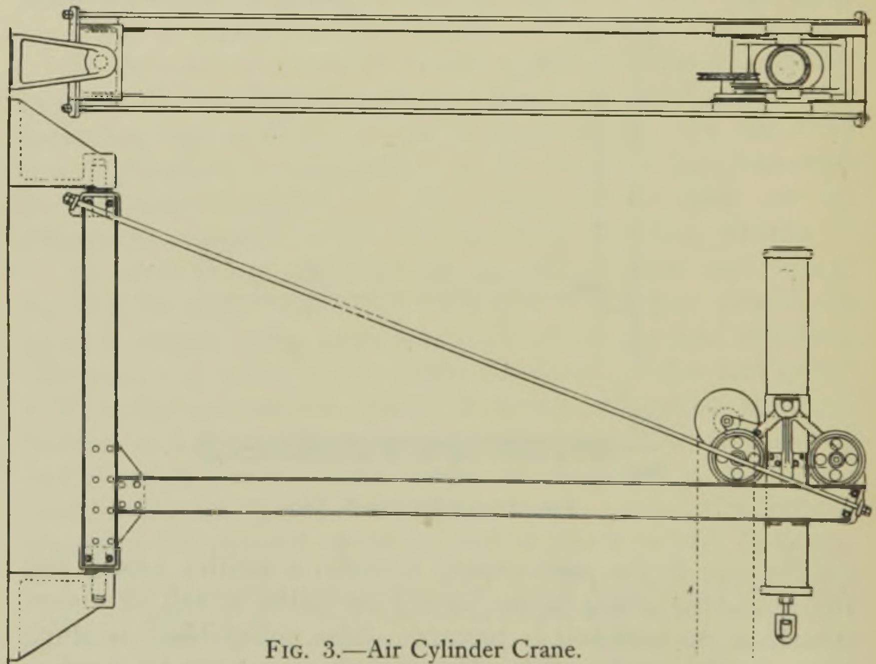

FIG. 3.—Air Cylinder Crane.

In another design of *pneumatic crane* useful in foundries (Fig. 4) the cylinder is fixed vertically between the steel channels forming the crane post. Here hoisting is effected by the chain anchored at A passing straight down and round the sheave B on the top of the cylinder, then up again and round two guide sheaves to the racking carriage or trolley carrying the bottom-block. The hook is traversed or racked by pulling on the vertical hand chain C. A flexible pipe supplies air at a pressure of about 100 lb. per sq. in. from an air compressor serving also a battery of pneumatic moulding machines and other tools. Of course it would hardly pay to install an air compressor merely to serve one or two small pneumatic hoists. In many large workshops and foundries, however, not only are compressed air and high-pressure water conveniently available, but also a supply of electricity, sometimes both alternating and direct current.

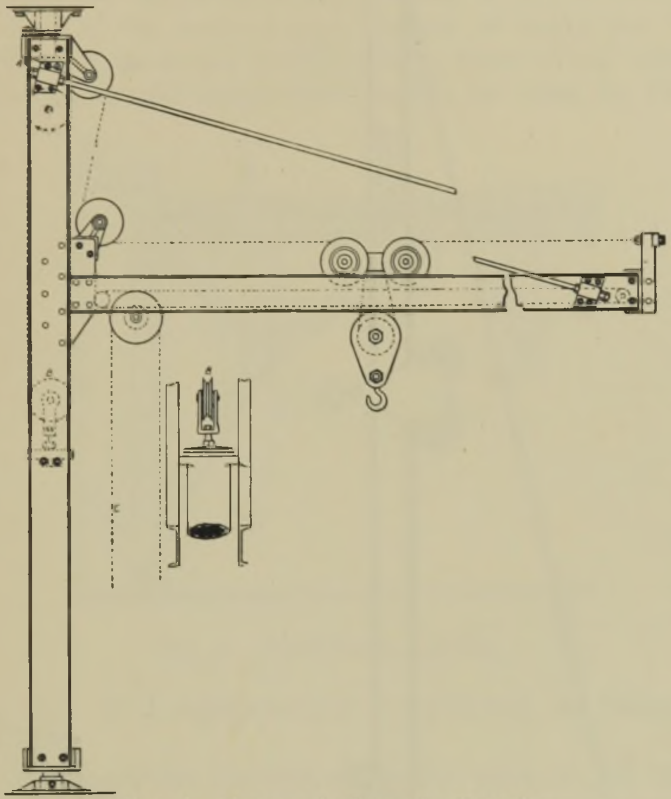

FIG. 4.—Pneumatic Crane for Foundry.

An adaptation of the smithy crane to water-pressure operation is given in Fig. 5. A good many light cranes of this simple type have been made in the past. In this *hydraulic crane* the lift is direct, the ram A being secured to the jib B, while the admission of the water is controlled by a suitable valve. The smooth motion of the jib is ensured by the two

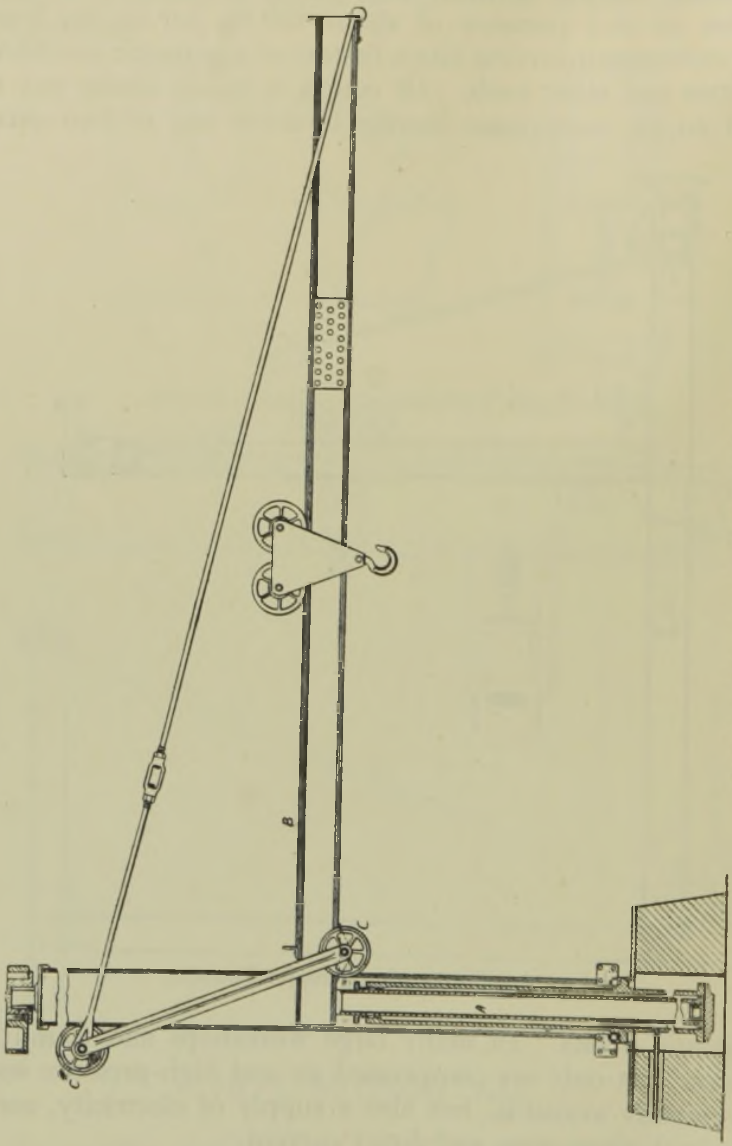

Fig. 5.—Direct-acting Hydraulic Crane.

flanged rollers B, bearing against the back and front of the guide post and linked together by connecting rods. The load slung from the hook (without pulley-blocks) is carried by a trolley, which in this case is not racked along the jib by a hauling gear, but is moved in the required direction by merely pushing against the suspended load. Turnbuckles provide a convenient means of adjusting the precise length of the ties connecting the end of the jib to the pin of the top guide roller.

Foundry Cranes.—In simple foundry cranes of the cantilever type, supported mainly from the ground to economize head-room, the horizontal trolley-track or jib is strutted below to the foot of the mast or post, instead of being tied to the top of the post as in the smithy crane. Some actual examples of lifting tackle and simple hand cranes (as made by Herbert Morris Ltd. of Loughborough) are pictured on Plates 1, 2 and 3.

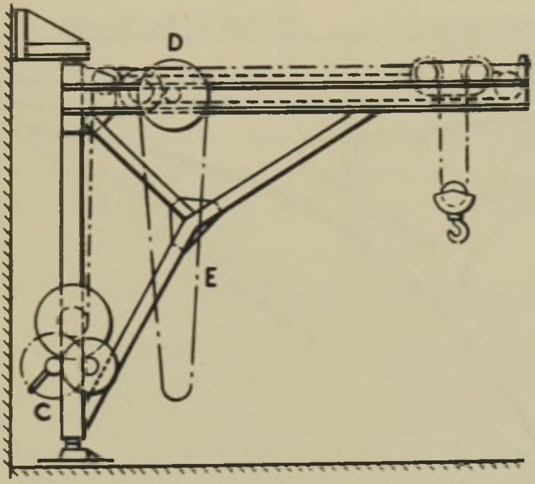

FIG. 6.—Hand Foundry Crane.

In old cranes the framing was often made of red deal, of pitch pine or of oak, but in modern foundry cranes the frame is always built up of steel sections. Fig. 6 shows a hand crane with steel framing and cranked jib. The four-wheeled trolley or ' jenny ' carrying the hook affords a convenient means of varying the radius of action or ' reach ' of the crane, its position being controlled by a haulage or racking chain winding on and off a barrel fixed at the top of the post and geared to a spider wheel D, turned by a light hand chain E. The return racking chain runs over a guide roller at the end of the jib.

The crane post is pivoted at top and bottom ; it rotates or ‘ slews ’ fully 180° but seldom through a complete circle. The hoisting gear C fixed on the post is shown double geared. The lifting chain is coiled on a cast-iron barrel or flanged drum, the remote end of the chain being anchored to the tip of the jib. The shafts are carried in cast-iron cheeks, bolted to the timber uprights at a suitable height above the ground for operating the handles. To control the load a hand brake, ratchet-wheel and pawl are fitted.

Such foundry cranes have been made in sizes ranging from 1 ton up to 10 tons lifting capacity, the heavier cranes being treble geared. But manual power is now usually displaced by electric motors, hand cranes being too slow and expensive for modern requirements.

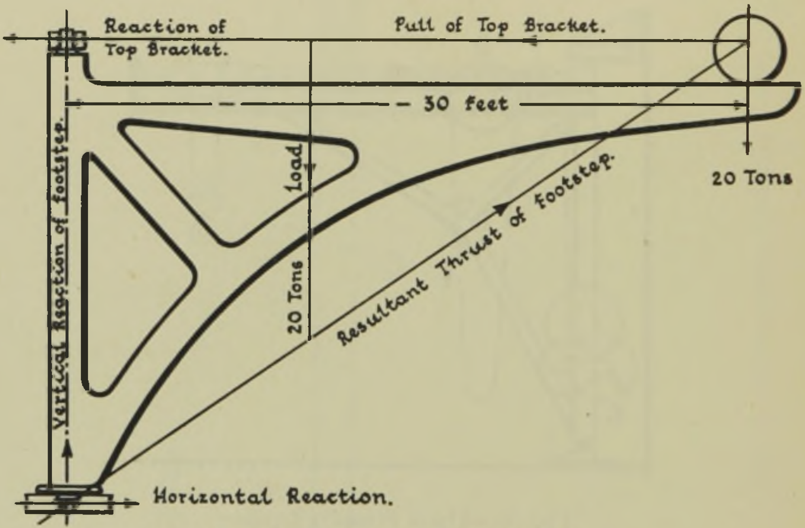

FIG. 7.—Forces on Cantilever Jib.

The general design of the foundry jib crane has not changed much for many years, though details and materials of construction have been improved greatly. Such jib cranes for internal workshop service, however, save for the lightest duties, have been largely displaced by overhead travellers, running on the elevated tracks common in the loftier foundries and machine shops now in vogue.

In an old 20-ton foundry crane of 30 ft. radius (Fig. 7) the cantilever jib is built up of steel plates and angle bars riveted together. It is curved in outline, in order to give as much clearance as possible for bulky loads, though this is a needlessly expensive mode of construction. The double side frame supports a trolley from which the load is slung. In this case the hoisting is done by means of a pair of steam engines, 6 in. diameter by 12 in. stroke, bolted to the post.

In considering the *external forces* acting on such a crane to preserve equilibrium we take turning moments about the footstep ; thus

$$R \times 20 \text{ ft.} - 20 \text{ tons} \times 30 \text{ ft.} = 0,$$

or

$$R \times 20 = 20 \times 30,$$

therefore

$$R = 30.$$

Hence the horizontal reaction of the top bracket is 30 tons. This is equal in magnitude to the horizontal component of the footstep reaction, the vertical component being equal to the load. The diagonal thrust is either calculated or scaled off a triangle of forces. This also gives the *direction* of the resultant, its magnitude being

$$\sqrt{W^2 + R^2} = \sqrt{400 + 900} = \sqrt{1300} = 36 \text{ tons.}$$

Of course this is true only of a weightless structure. When taking account of the weight of the crane itself it is first necessary to determine the centre of gravity of the whole machine. But as a rough guess assume here that the weight of the crane acts vertically at 6 ft. from the centre line of the footstep bearing and that the crane weighs 12 tons. Then the additional horizontal reaction r due to this weight will be given by equating the moments, thus

$$r \times 20 \text{ ft.} = 12 \text{ tons} \times 6 \text{ ft.},$$

from which $r = 3{\cdot}6$ tons. Thus the total horizontal reaction due to the loaded crane is $R + r$ or 33·6 tons.

Stress Diagrams.—It is instructive to utilize the methods of graphic statics in drawing diagrams showing the longitudinal stresses in the members of simple braced frames. Taking first the case of a small wall crane (Fig. 8) with a load suspended from the end of the inclined jib, we first draw a skeleton frame diagram and letter the spaces between the forces in accordance with Bow's convenient notation.

Then set off the load line *ab* to represent, say, 1000 lb.

From *a* and *b* draw lines, intersecting at *c*, parallel to the corresponding lines in the frame diagram. Insert direction arrow-heads to show the thrust of the strut *bc* and the pull *ca* of the tie, also opposing arrow-heads at the other ends of the bars. Proceed similarly in a clockwise angular direction at each joint in turn, until the complete stress diagram has been drawn. The joints are here taken in the order marked in Fig. 8. For the sake of clearness the lines representing compressive forces are thickened, while *thin* lines represent tensile forces.

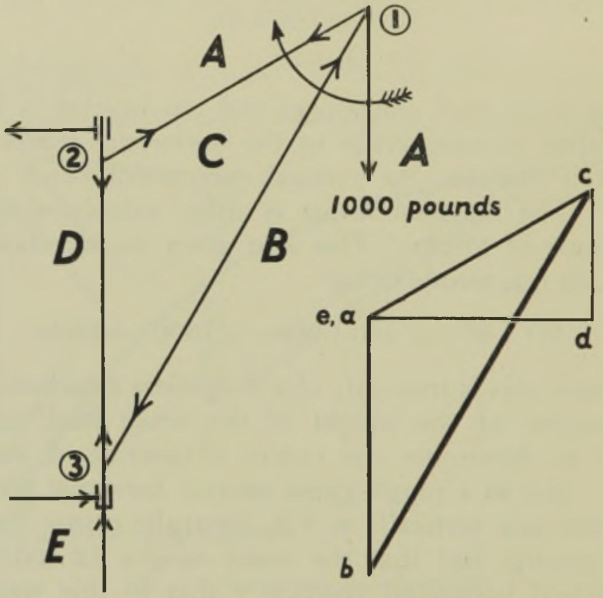

Fig. 8.—Frame and Stress Diagrams for a Wall Crane.

Alternatively the external reactions and the internal stresses may be calculated arithmetically by taking moments about several points. Then the various details of the structure may be suitably proportioned to withstand the forces coming upon them ; having regard to the strength of materials, the methods of applied mechanics and the requirements of workshop practice as well as convenience of erection.

Taking another simple case, Fig. 9 shows the stress diagram for a foundry jib crane reduced to the skeleton form. Here the dotted part of the horizontal jib is subjected to a *bending* moment only (neglecting the chain tension) and is not part of the triangular frame. In some designs of light foundry cranes built up of steel channels, the lower strut is prolonged upwards to meet the jib, both as a manufacturing convenience and to increase the stiffness of the frame.

The influence of the chain tension and the weights of the parts can be dealt with separately, and then added to the stresses arising from the load lifted. The weight of each bar has to be transferred to its joints when considering the influence of gravity.

The vertical and horizontal forces acting on the structure

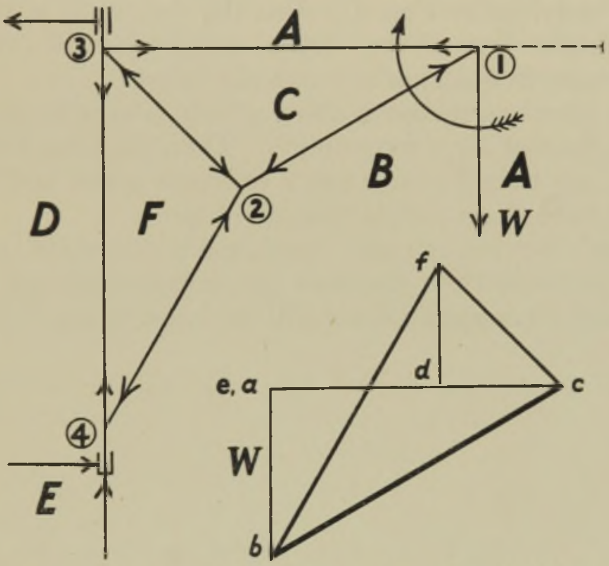

Fig. 9.—Frame and Stress Diagrams for a Foundry Crane.

to preserve equilibrium are indicated by the lines *ab*, *bc*, *cd* and *da*. Wind pressure is here disregarded, as cranes for internal use are not exposed to wind storms. The big assumption is also made that the bars or members of the frame are connected by frictionless pin joints, whereas the actual gusset plates and riveted joints do really cause some bending stresses on the bars. Unless this convenient assumption is made, however, the ordinary methods of estimating stresses are inapplicable.

Laws of Equilibrium.—Before leaving this chapter it will be helpful to summarize the general laws or conditions of equilibrium of a rigid structure or body acted upon by any number of forces in one plane, namely :—

(1) The geometrical or vector sum of all the external forces must be zero or *nothing*.

(2) The algebraic sum of all the turning moments, taken about any centre of rotation whatever in the plane of the forces, must also be *nothing*, opposite directions being considered of unlike sign.

The first of these conditions of equilibrium is satisfied if a *closed* polygon can be drawn to represent the forces acting on the body, as in Fig. 8. Also the condition is satisfied if the algebraic sums of the vertical and horizontal components of the forces in question are severally *nought*.

The commonest case is when a body is kept in equilibrium by the action of *three* forces only. Then the force lines, if not parallel, are bound to meet at a common point, and the force polygon becomes a simple triangle of forces.

Some use has already been made of these important principles to find the reactions and stresses induced by given loads, and other applications will be made in later chapters.

CHAPTER III

DERRICKS AND MASTS

For regular *inside* work the overhead electric traveller, spanning each bay of a large workshop, doubtless excels all other forms of crane in general utility. Yet for occasional *outdoor* work the most generally useful type of hoisting machine is probably the derrick crane, with its long swivelling jib or boom,[1] commanding an extensive field of action. For its capacity and flexibility this is a relatively simple and cheap form of crane.

The derrick is pre-eminently the crane for *temporary* duty, as in erection operations on the site of a lofty steel-framed building, or in carrying out civil-engineering contracts in the open air. It finds favour also in the yards of timber and scrap-metal merchants, and in quarries and contractor's yards. Shipbuilders, too, utilize groups of high derricks extensively in large steamship construction ; though for this work the tower cantilever crane is even more popular, hundreds of them being prominently displayed against the sky-line on the Clyde, the Tyne and the Mersey shipyards.

The derrick crane is a general-purpose tool rather than a special machine designed for single-purpose repetition work, such as a high-speed wharf crane working against time and tide in loading and unloading ships. Besides lifting isolated heavy loads at rather infrequent intervals, the derrick can be readily adapted for grabbing bulk material like coal from the holds of colliers and barges, as well as for operating an electric magnet in a foundry yard.

Guy Derricks.—There are several types of derricks, the simplest being a guyed derrick pole or mast, used for erection work in conjunction with either pulley-blocks or a winch. The mast may be made either of timber or of steel angles and

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[1] American engineers favour the term ' boom ' for an *inclined* jib.

flats. Only a very limited movement in the horizontal plane is possible, however, with this simple tool.

Much more like a real lifting machine is the guy derrick type of crane complete with jib, as shown in Fig. 10. Here, in addition to the pivoted mast with cap, held vertical by four or more galvanized steel wire rope guys, we have a lattice jib, capable of swivelling around or slewing about a vertical axis, and also capable of luffing or hinging about a horizontal axis, so as to vary the radius of the hook. To these must be added suitable anchorages in the ground, placed well away from the mast baseplate, also hoisting and luffing ropes, bottom-block and winch, operated either by hand or by steam or electric motor and controlled by brakes. In the figure C is the working

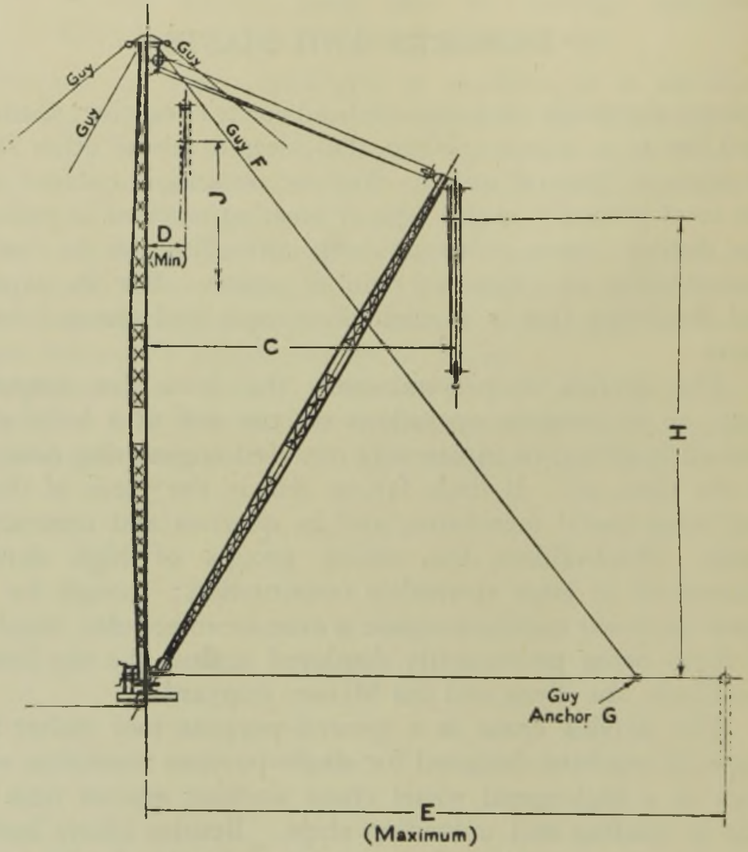
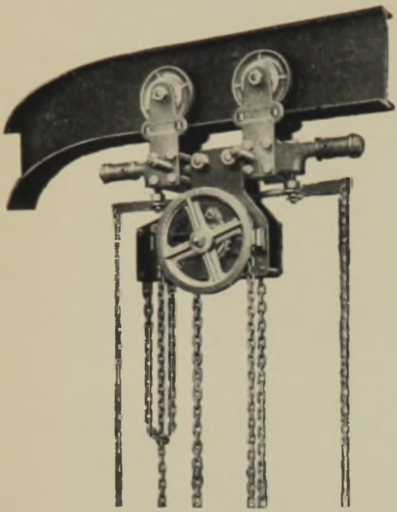
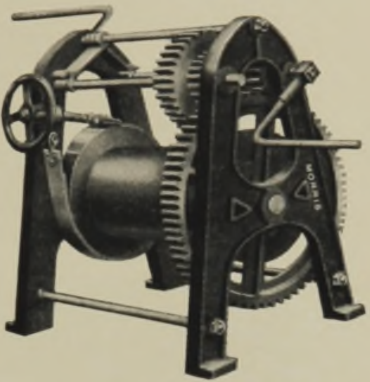


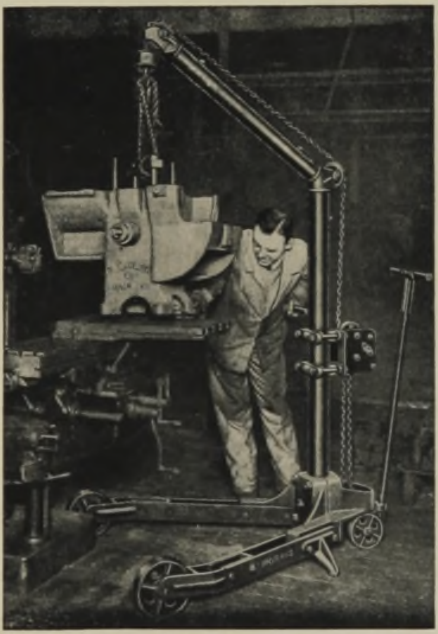
Fig. 10.—Guy Derrick Crane.

PLATE 1


PULLEY-BLOCK ON TROLLEY.



HAND WINCH.


PORTABLE HAND CRANE.

[*To face page* 16.

PLATE 2

LIGHT SMITHY CRANE.

LIGHT FOUNDRY CRANE.

LIGHT ROOF CRANE.

Herbert Morris Ltd.

To face page 17.]

radius in the position shown and H the corresponding height of lift, while D and E are the minimum and maximum possible radii.

Some very high guy derricks have been made for shipbuilding yards. In one example 5 tons can be hoisted to a height of 120 ft. at a radius of 35 ft. from the centre of the lattice mast, which is 6 ft. square at the centre tapering to 18 in. at the ends. The jib stands at an angle of 45° and is slewed by a motor in the driver's cabin, which stands 95 ft. above the ground. The hoisting winch is set on the ground and driven by a 30 H.P. motor, the rope passing up inside the mast, through the jib foot pin, and then around a guide sheave [1] to the jib-head sheave. The two lifting speeds available are 90 and 210 ft. per minute.

Formerly derrick masts and jibs were often constructed of wood, which is still used in some out-of-the-way places. The following short table, based on American practice, gives recommended lengths and sections of the masts and jibs for timber derricks equipped with iron and steel fittings :—

Lifting Capacity	Mast		Jib	
	Length	Section	Length	Section
Tons	Ft.	In.	Ft.	In.
$1\frac{1}{2}$	34	8 × 8	25	6 × 6
3	42	10 × 10	34	8 × 8
6	50	12 × 12	40	10 × 10
10	55	14 × 14	45	12 × 12
16	60	16 × 16	50	14 × 14
24	65	18 × 18	55	16 × 16

For heavy derricks steel construction is naturally preferable to timber work, not only because steel is more readily available in suitable sections but on account of its greater durability and the greater accuracy with which its strength may be determined. The lattice-framed mast and jib have to be so

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[1] A '*sheave*' is a grooved wheel for either rope or chain running freely on a pin and not keyed on to a shaft. The term *pulley* tends to be rather overworked, being often used loosely for any sort of a wheel that turns round, even if a chain sprocket-wheel.

proportioned as to give the required strength against collapse under load and to resist the torque due to slewing the derrick. In America steel guy derricks range in lifting capacity up to 100 tons or more, while those built for unusual service conditions sometimes have jibs as long as 125 ft.

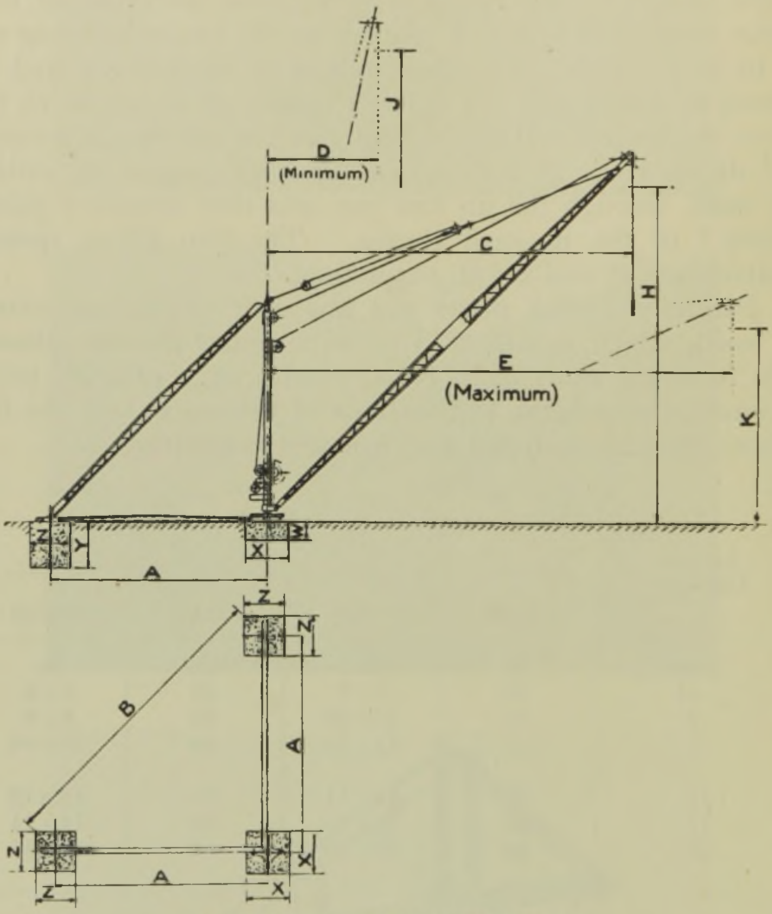

FIG. 11.—Scotch Derrick Crane.

Scotch Derricks.—For less temporary service the Scotch[1] derrick (Fig. 11) is more suitable than the guy derrick. In this type rope guys are omitted, and the mast is supported by two inclined 'back-stays' or 'stiff-legs' at right angles and by two horizontal 'sleepers' or 'sills' A anchored down

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[1] The name 'stiff-leg derrick' is commonly used by American engineers.

either temporarily by heavy weights or permanently by foundation bolts and plates to concrete anchor blocks. In erection work a heavy bogie running on rails is often arranged below the mast and another below the end of each sleeper. For safety an additional horizontal stay may be lashed diagonally across the two sleepers. By thus mounting the derrick on heavily loaded bogies it is easily moved along the rails from time to time as the work progresses.

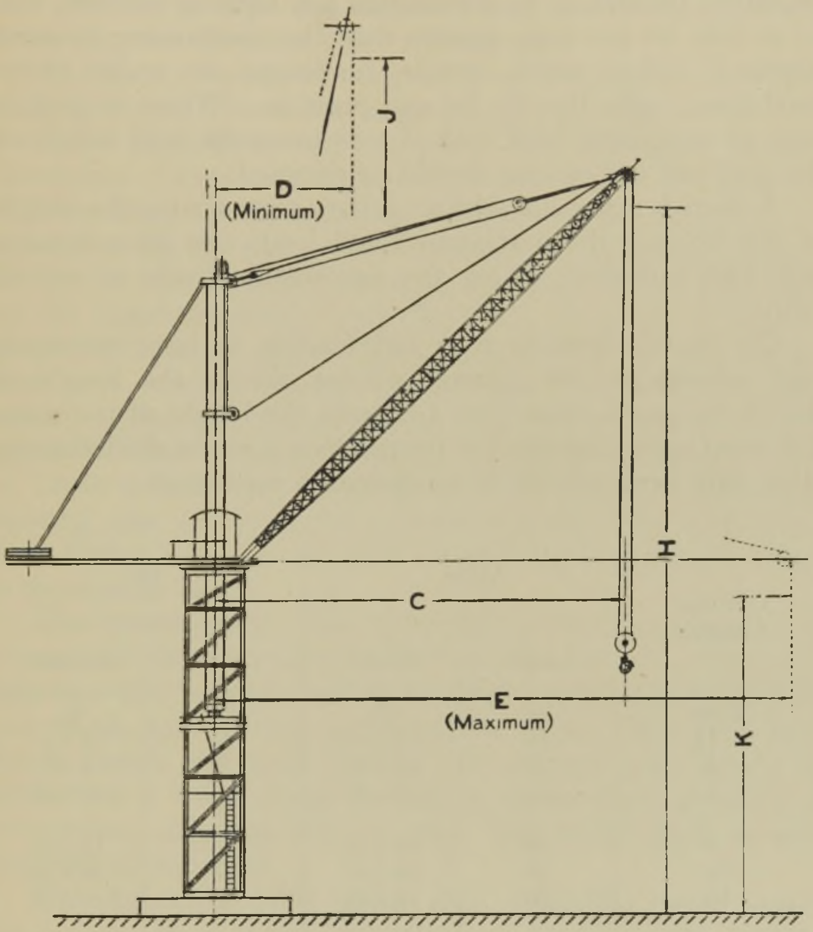

FIG. 12.—Tower Derrick Crane.

Scotch derricks may be erected at either ground level or considerably above it, even at the top of a high building in the smaller sizes. But for very high lifts H the alternative form known as the *tower derrick* is available, as shown in Fig. 12, where K is the minimum height of lift. These diagrams are adapted from British Standard Specification No. 327, to which reference may be profitably made.

To ensure stability it is suggested that the anchoring or ballasting be such as to ensure that the righting moment will be at least 50 per cent. greater than the overturning moment imposed, either under service conditions or under storm conditions, with the jib in *any* position. Where a *grab* is used an equivalent hook load of 1·33 times the total weight of the grab and its contents should be assumed.

A derrick crane should have a data plate stating the length of the jib and the maximum rated load, also an automatic safe load indicator, giving the permissible loads at various radii.

On Scotch derricks it is not feasible to have extremely high masts, nor for general service should the length of the jib be much more than 1·5 times the height of the mast. For *wood* masts and jibs the proportions given in the following table have been arrived at by operating experience :—

Lifting Capacity	Mast		Jib	
	Length	Section	Length	Section
Tons	Ft.	In.	Ft.	In.
1½	16	8 × 8	25	6 × 6
3	22	10 × 10	35	8 × 8
5	26	12 × 12	40	10 × 10
8	30	14 × 14	45	12 × 12
12	33	16 × 16	50	14 × 14
18	36	18 × 18	55	16 × 16

In the past, red deal, pitch pine and oak have been much used, along with cast-iron fittings. But the employment of timber struts in cranes almost ceased when the introduction of mild steel gave us large rolled steel sections, viz., flats, angles, channels and joists, which are so easily connected together by gusset plates and rivets or by electric welding.

Derrick Gear.—This is the gear whose function is to vary the radius of the crane jib throughout its range. Some cranes have the derrick gear separate from the hoisting gear, but a true derrick crane has the two gears coupled together. By this latter arrangement the hoisting chain is payed out when the jib is derricked in and *vice versa.* The result is that the load is kept at a constant level, or nearly so, which is not the case when the gears are separate.

The mere coupling of the gears does not always ensure the load moving in a horizontal line, although in some derricks the result is sufficiently approximate. The original inventor, Henderson (1845), made the *derrick* barrel itself in a conical or fusee form, and so arranged it that when the jib was at its greatest radius the chain was winding on the smallest diameter. As the jib was derricked inwards, the chain wound gradually on the larger diameters and therefore payed out a shorter length of hoisting chain. This compensated for the inconstant ratio existing between the movement of the jib and the needed paying out of the hoisting rope to keep the load horizontal. When a derrick crane is required to simply hoist or lower a load, the derrick gear is disconnected from the hoisting gear by means of a *clutch*, the jib being prevented from falling [1] by the aid of a ratchet-wheel and pawl fitted to the derrick barrel.

The photographic view (Plate 4) of the lower part of a 5-ton *hand* derrick crane by Butters Bros. & Co., Glasgow, indicates the hoisting and derricking barrels (or drums) as well as the spur gearing actuating the same. The view also clearly shows the hand slewing (or slueing) gear, which is worked by a hand wheel through a worm-wheel drive to a race-pinion, engaging with a large race-wheel fixed to the baseplate of the crane.

The following table gives data regarding some main dimensions of a range of standard *hand-operated derrick cranes*, having capacities of 1 to 10 tons. The maximum height raised may be taken as equal to the length of the jib.

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[1] The fall of a jib is perhaps the most serious accident that may happen with a Scotch derrick crane. This accident may generally be prevented by providing a proper *interlocking device* between the clutch and the pawl or a self-locking device on the derricking drum. Several of such mechanisms are illustrated in the Home Office Pamphlet, No. 15, referred to on page 4.

Length of Jib	Radius of Hook			A. Sleeper Centres	B. Cross Centres
	Full Load	At ⅓ Load	Least		
Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
20	14	19	4·5	10	14
30	20	28	6	15	21
40	28	38	7	20	28
50	35	46	9	25	35
60	42	56	10	28	40
70	50	65	12	32	45

Power Cranes.—Larger cranes are commonly driven either by a twin cylinder engine or by one or two electric motors, in each case a clutch shaft being introduced to control the various operations. See the line drawing, Fig. 13.

The *hoisting* drum is driven by a train of spur gears, a brake being mounted on the second motion shaft, and always kept in gear with the drum, though disconnected from the driving shaft by a jaw clutch.

The *luffing* [1] or derricking drum is driven by spur wheels through the hoisting drum, their relative speeds being designed to give a nearly level path to the hook when luffing. The speeds are so arranged that when the luffing rope is wound on to its drum, a proportionate length is unwound from the hoisting drum.

For safety the *luffing* drum carries a ratchet-wheel whose pawl lifting gear is interlocked with the luffing clutch lever, so that the pawl cannot be lifted clear until the clutch is engaged, after which the hoisting brake becomes effective as a luffing brake. Another brake on the *slewing* gear is also fitted, in order to check the bodily rotation of the crane about the axis of the mast.

On the larger derrick cranes a light load change-speed gear is provided, giving a hoisting speed about three times faster than the normal full-load speed.

When designing a derrick crane to meet the requirements of B.S.S. No. 327, it is necessary to provide a

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[1] The terms ‘ derricking ’ and ‘ luffing ’ are synonymous, meaning the operation of varying the radius of the hook.

factor of safety of at least 4·5 for all parts of the crane structure; and a steady wind pressure of 5 lb. per sq. ft. must be allowed for when the crane is in operation. But when the crane is at rest under storm conditions, it must be capable of withstanding the severe wind pressure of 35 lb. per sq. ft. Under either of these conditions, the calculation is to be made on an area equivalent to 1·5 times the projected

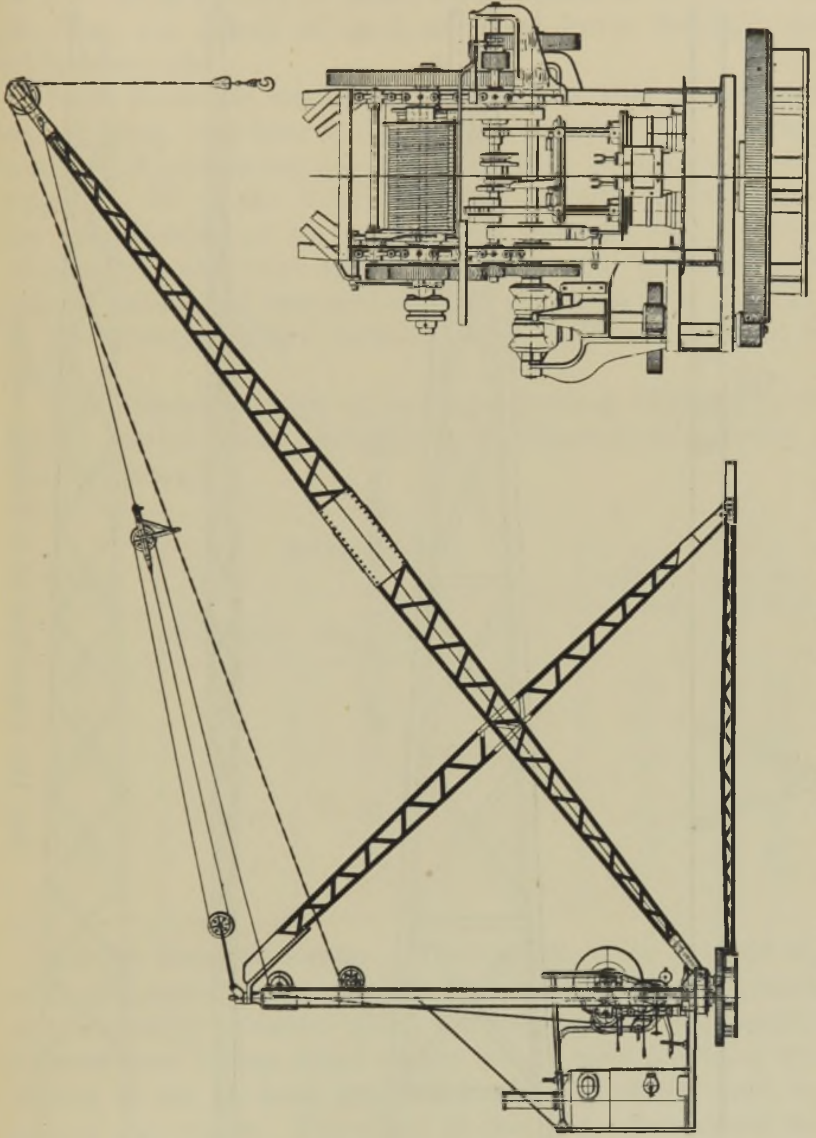

FIG. 13.—General Drawing of Steam Derrick Crane. (Butters Bros. & Co.)

area of the unloaded crane, save that only the actual projected area of cabins and machinery houses need be taken.

Struts.—The *slenderness ratio* of a strut is a figure of great

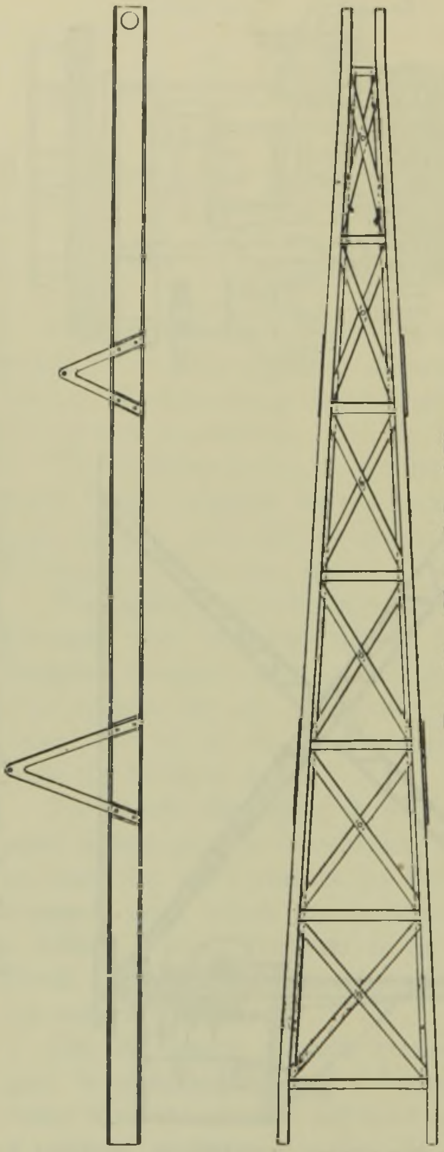

Fig. 14.—Channel Steel Jib.

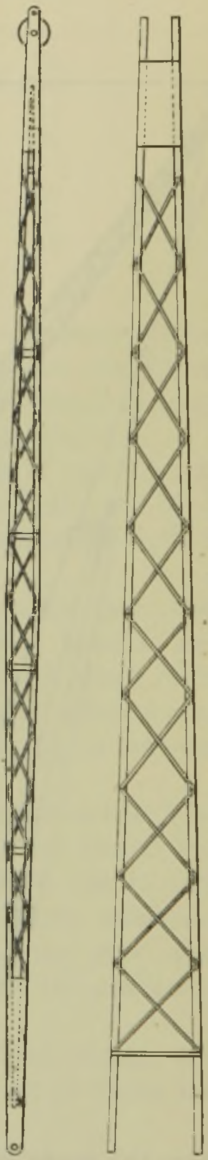

Fig. 15.—Lattice Steel Jib in Elevation and Plan.

importance when checking the strength and sufficiency of a mast, jib, back-stay or sleeper. This ratio is obtained by dividing the full length of the strut in inches by the minimum radius of gyration in inches of any cross section within the middle third of its length. It must not exceed 100, whether the strut members are channels connected by latticing (as in Fig. 14) or entirely of lattice construction, as in the derrick jib (Fig. 15). Both of these are good forms for light and fairly heavy jibs.

Such struts are subjected to combined axial compression and bending, and have to be designed accordingly. General methods of calculating the stresses in long struts are given in Appendix IV to the B.S.S. No. 327. Firms specializing in the manufacture of jib cranes will naturally have reduced all such formulæ, rules and regulations to the handy shape of graphs, tables and standard designs of details ; as produced in the drawing offices housing their well-trained technical staffs.

The following table gives some leading dimensions for Scotch derrick cranes when driven by either electric motors or steam engines :—

Length of Jib	Radius of Hook			A. Sleeper Centres	B. Cross Centres
	Full Load	At ⅓ Load	Least		
Ft.	Ft.	Ft.	Ft.	Ft.	Ft.
50	38	47	9	22	31
60	45	57	10·5	26	36·5
70	52	67	11·6	30	42·5
80	60	76	12·5	34	48
100	75	96	15	42	59
120	90	115	17·5	48	68

Lever Derrick Crane.—The design of an unusual type of derrick crane is given in Fig. 16. This is of interest mainly as introducing a feature which has been applied very successfully in level luffing wharf cranes, viz., a twin quadrant lever, hinged to the jib head and tied to the top of the mast by a pair of guy ropes. The effect of this is to give almost level luffing in a simple manner.

Here the luffing motion is quite independent of either hoisting or slewing, though luffing may proceed simultaneously with both of these movements. It is controlled by

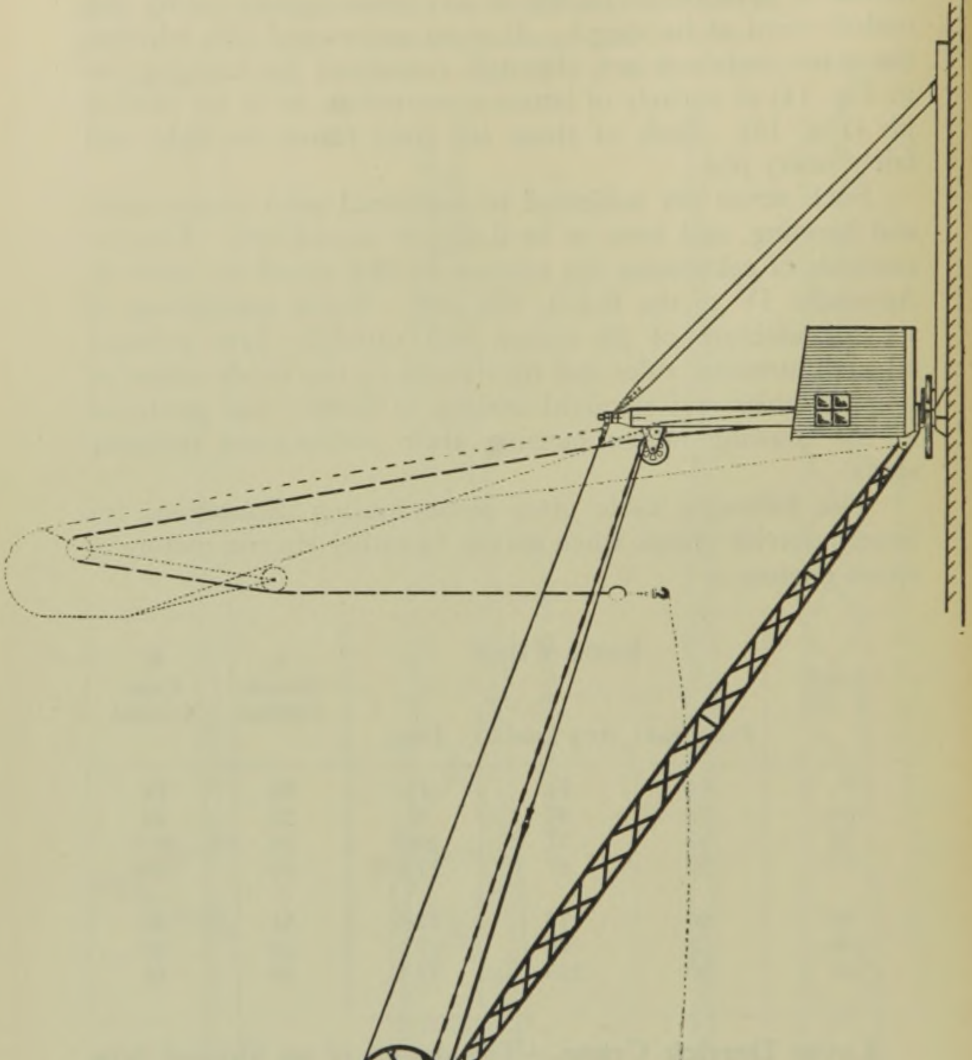

FIG. 16.—Special Lever Derrick Crane. (Babcock & Wilcox, Ltd.)

one hand lever. The guys fixing the lever to the mast act as check ropes, preventing the jib from running out too far. When carrying a heavy load on the hook, the jib checks itself without shock, just beyond the rated maximum radius. Though the jib is not balanced, the load is over-compensated, which has much the same effect. Another advantage is that the speed of luffing *drops* as the least radius is approached, instead of increasing rapidly.

On the lever derrick crane the support of the jib is quite automatic, thus permitting the luffing clutch to be safely thrown in and out hastily ; whereas on an ordinary derrick this operation must be done with great care, to avoid shock and some danger in careless hands. This crane is driven by a single continuously running electric motor, through a Hollick friction gear, which gives better management of the swinging load than does a controller.

BRAKES

As the force of gravity is always acting to lower both the suspended load and the unbalanced jib, reliable brakes are essential in every crane, while a safety interlocking device is very desirable.

In most cranes the load is capable of being lowered on the brake, so that when the load is suspended it can be so retained for an indefinite period by the friction of the brake ; also, by momentarily releasing such friction, the load can be lowered to any extent desired and again arrested by putting on the brake.

A simple form of automatic brake is used on various types of cranes, consisting of a strap brake with a weighted lever. The drum is made in two parts, the outer portion upon which the strap operates being free to revolve upon the shaft, while the inner part is keyed to the shaft and engages with the outer part by means of ratchet pawls, which are effective only in the lowering sense. Thus the brake drum is always free to revolve in the hoisting direction, but the load can be lowered only by allowing the outer portion to revolve.

Brakes are most important details of hoisting machinery. Increasing weights and speeds demand better and more efficient means of coming to rest safely and quickly. Modern high-speed electric cranes have powerful automatic brakes fitted to every motion. In many cases during a cycle of operations the period of acceleration has hardly terminated when rapid retardation is effected by the brake, the few seconds thus saved on each movement showing a considerable economy of time on the day's run in the aggregate.

In its simplest form the brake is merely a smooth turned wheel or flanged drum embraced by a thin strap of steel, either with or without an intervening flexible lining of wood, leather, fabric, ferodo or other material. Fig. 17 represents the arrangement, from which it is seen that immense leverage is capable of being exerted on the strap. The lever is worked by either hand or foot, and it may be on the right or the left hand side. The brake drum is placed on either the second or the third motion shaft, in order to gain the greatest purchase. It may be cast as a ring on the barrel wheel or it may be a separate ring with arms and keyed on independently, the former being preferable.

In Fig. 17 the leverage exerted at A on the length *a* of the lever B sets up tension in the strap *b*, with friction round the brake drum C ; which in this case is shown on the same axis as the barrel D, whence the load on the chain or rope E is controlled. The effectiveness of the brake depends to a large extent on the proportion of the circumference that is embraced by the strap, usually about three-fourths.

Fig. 18 is a section through a brake drum when cast as a separate wheel. Preferably, however, brake drums are cast on spur wheels. Fig. 18 also shows a typical brake strap, made of a strip of steel, riveted to straps at the ends, with eyes for the brake pin. In some brakes the straps are lined with short blocks of wood (willow or poplar), from 3 to 4 in. wide, screwed to the strap and renewed when they become worn.

Fig. 19 indicates an early form of *electro-magnetic brake*, with two solenoids through which the electric current passes, holding down the keeper on the end of the lever and keeping the brake strap off. Should the current be cut off, or fail from any cause, the keeper is released by the weakening of the magnetic field, and the counterweight at the free end of the lever instantly pulls the brake on. The action of the brake is made more gradual by a small spring buffer placed close to the solenoids, which are shunt wound.

According to the B.S.S. No. 327, the *hoisting*-motion brake of a derrick crane must be designed to exert a restraining torque amounting to 25 per cent. greater than the torque transmitted, under service conditions, to the brake drum from the suspended maximum rated load, excluding the friction in the transmission details between the load and the brake.

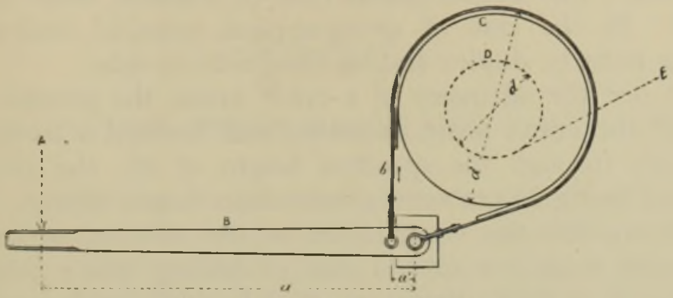

FIG. 17.—Simple Band Brake.

Moreover it is recommended that a mechanically operated *hoisting*-motion brake be provided either on the hoisting drum shaft or on the pinion shaft. In no case should the braking of the hoisting motion or of the derricking motion be dependent solely on electrically controlled braking appliances.

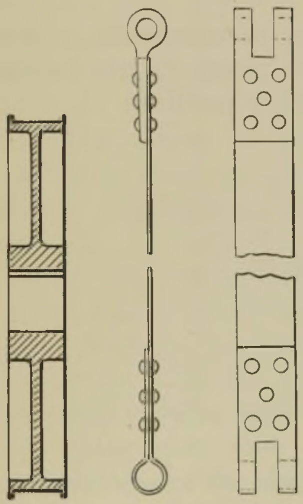

FIG. 18.—Brake Drum and Strap.

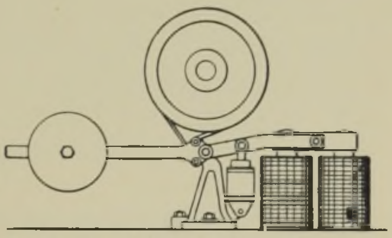

FIG. 19.—Electro-magnetic Brake.

Where *solenoid brakes* are fitted they must apply the braking torque as soon as the current is cut off from any cause whatever, even after the lining and fittings have become worn. To prevent shock either a dash-pot or its equivalent must be provided. The *weight*-loaded type of solenoid brake is preferred. In the case of *spring*-applied solenoid brakes, the springs must be duplex and be fitted side by side.

To test the adequacy of a crane brake, the greatest rated load of the crane must be raised and lowered 5 times continuously through the specified height of lift, the speed of lowering being 25 per cent. greater than that of lifting. After this severe test the temperature of the rubbing surfaces of the brake must not exceed that of boiling water (212° F.) with wood or fabric lining, or 400° F. with bonded asbestos or metal lining.

In the case of brakes applied by the *foot*, a force of 70 lb. on the pedal must be sufficient to exert the required restraining torque, while in the case of *hand* brakes a force of 35 lb. applied at the handle must suffice. In either case a locking device, capable of sustaining 50 per cent. above the greatest rated load, must be provided.

Finally, in addition to the hoisting-motion brake, a *slewing* brake must be fitted in an accessible position, and provision made for it to be secured in the holding position.

CHAPTER IV

FIXED CRANES, THEIR BASES AND FOUNDATIONS

Of recent years there has not been the same demand as formerly for *fixed* cranes, preference being given to *movable* cranes for convenience and general utility. Some very large cranes have been mounted on barges or pontoons, thus enjoying the superior mobility of *floating cranes*. A good example is the 150-ton 'London Mammoth,' which is mounted on a pontoon 200 ft. long and is self-propelled.[1]

Such floating cranes can pick up a 3-ton wharf crane bodily and transport it a mile or more up or down stream and place it on another wharf. They are also capable of performing other duties of the heaviest character.

In a *fixed* crane the stability depends on its foundation, and in a *portable* crane it depends on the load and the relation between the radius of the hook, the gauge and the wheel-base, or an artificial base formed by blocking girders or rail clips. In a portable crane the truck or carriage forms the foundation.

Fixed Foundations may be divided broadly into two classes, viz., (1) those in which the mast or post goes down no further than the baseplate or the ground line, and (2) those for deep posts, as in the old curved-jib Fairbairn crane. Another division is that between cranes whose posts are rigidly *fixed*, with the structure alone revolving, and those whose posts *revolve*, with the superstructure attached to and also revolving with them.

Foundations of the *shallow* type are shown in the illustration of the Scotch derrick crane (Fig. 11). The relatively thin block of concrete under the mast is subject to a downward load only, whereas the deeper blocks under the back-stays have to sustain either a thrust or a pull, according to the position of the jib. The tails of the sleepers are secured by

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[1] See page 192, Chapter XIV.

bolts going down to the bottom of the foundation. The following table gives particulars of concrete foundations for four sizes of power derrick cranes driven by either motor or engine :—

POWER DERRICK FOUNDATIONS

Capacity of Crane	1½-ton	3-ton	6-ton	12-ton
Centre Foundation—				
Side of square	4′ 9″	6′ 0″	7′ 3″	9′ 0″
Depth of block	1′ 6″	2′ 0″	2′ 9″	4′ 0″
Cubic yards	1·25	2·75	5·5	12
Weight in tons	2	4·5	9	19·5
End Foundations—				
Side of square	4′ 9″	5′ 6″	6′ 9″	8′ 6″
Depth of block	4′ 6″	5′ 6″	6′ 9″	8′ 0″
Cubic yards	3·75	6·25	11·5	21·5
Weight in tons (each)	6	10	18·5	35

Thus the *total* weight of concrete in the three foundations for a 3-ton power crane amounts to, say, 25 tons, and for a 12-ton crane to 90 tons. The foundations for *hand* derrick cranes may be slightly lighter, as the speeds and shocks are so much less. The great increase in the mass of foundations which is rendered necessary by increase in the size of cranes is emphasized by these figures.

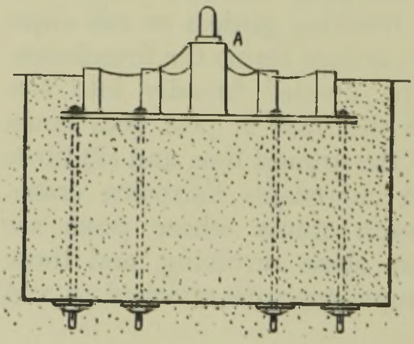


FIG. 20.—Derrick Mast Foundation.

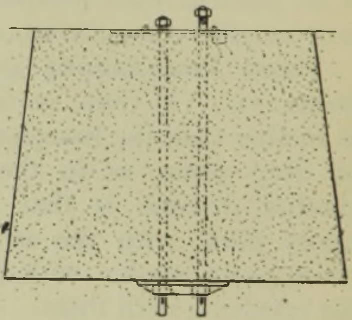
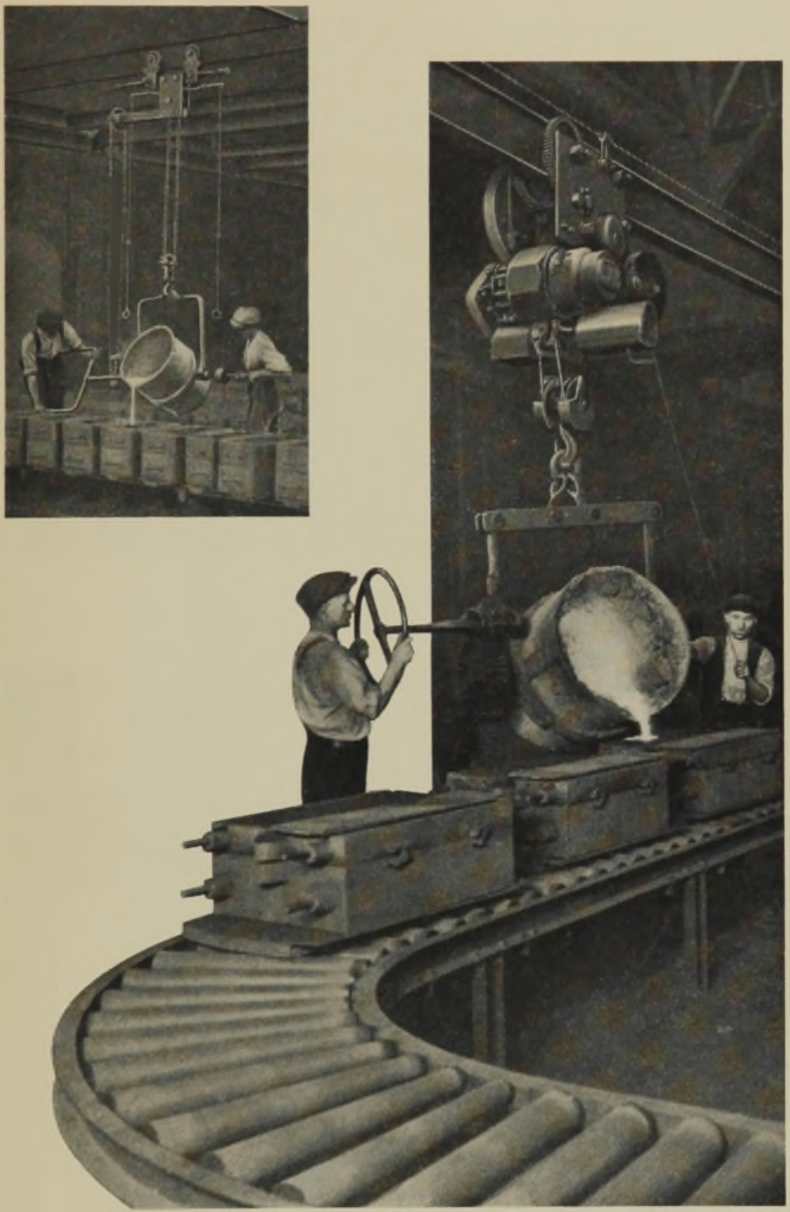


FIG. 21.—Sleeper End Foundation.

The sort of foundations that have been used below the *mast* and the *sleeper* ends of a big derrick crane are shown in Figs. 20 and 21 respectively. In each case the foundation bolts pass through broad washer plates at the bottom. The

PLATE 3

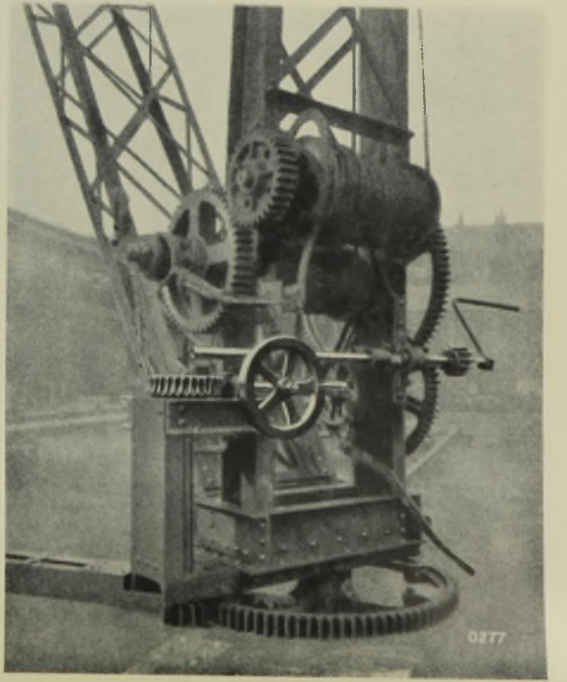


Herbert Morris Ltd.

POURING IRON INTO MOULDS FROM LADLES, USING HAND AND ELECTRIC RUNWAYS.

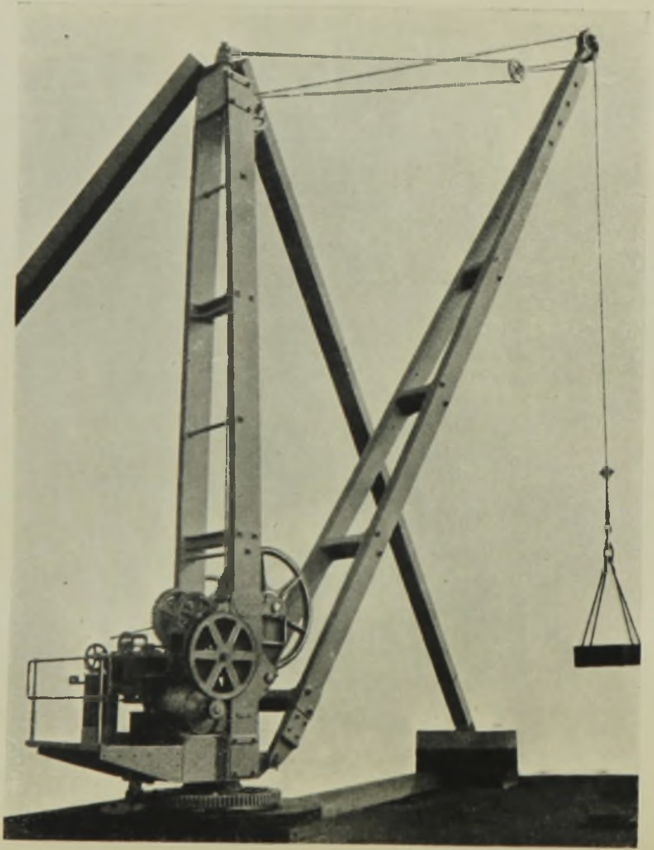
[*To face page* 32.

PLATE 4



Butters Bros. & Co.

HAND SLEWING GEAR OF DERRICK.



Thomas Smith & Sons, Rodley.

ELECTRIC DERRICK CRANE, SINGLE MOTOR.

To face page 33.]

centre casting carries both the mast pivot and the slewing ring, the latter being bolted down on the top faces of six bosses in this detail.

Piled Foundations.—Given ordinary conditions of soil, it is an easy matter to provide a sufficient mass of either concrete or masonry to ensure the stability of a fixed crane on a firm foundation. But for heavy cranes erected on unsuitable ground, it is necessary to prepare extensive and costly foundations. Heavy piling, or even sinking concrete cylinders, may be required to prevent the settling of the masses of concrete necessary for stability. The foundations should be such that the pressure of the guide rollers on the circular path does not cause the guide path to spring, since a slightly yielding path adds considerably to the force needed to slew the crane.

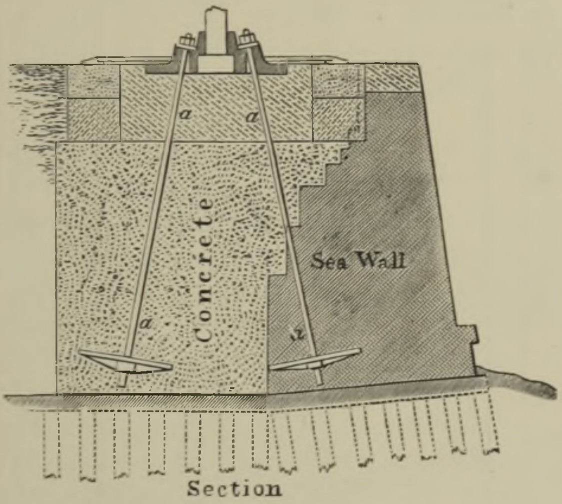


FIG. 22.—30-ton Wharf-crane Foundation.

The piled foundation sectioned in Fig. 22 is suitable for a 30-ton crane situated on a solid wharf, whereas that shown in Fig. 23 [1] is adapted for a similar crane erected at some distance from a wharf, in order to get sufficient depth of water to allow large vessels to come under the crane hook. Owing to the isolated position of the latter crane, enough concrete

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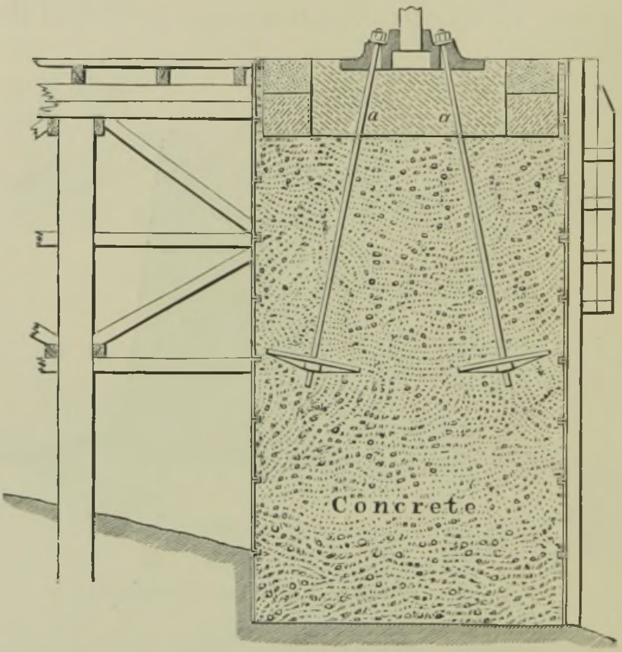
[1] From Sir John Anderson's "The Strength of Materials and Structures," by courtesy of Longmans, Green & Co. Ltd.

had to be placed in the foundation to render it fully stable statically, and make it capable of resisting any force tending to overturn it, quite independently of the light jetty itself. The cast-iron block holding the crane post is secured to the mass of concrete by means of four holding-down bolts *a*, of 4 in. diameter, each bolt being fixed to a strong cast-iron foundation plate 6 ft. square, embedded in the concrete.

When designing a crane foundation, regard must be paid not merely to the static load and the wind pressure but also to the possible dynamic forces or shocks which may arise due to the sudden checking of a heavy falling weight. A factor of safety of at least 5 must be allowed.



Section

FIG. 23.—Jetty-crane Foundation.

The 30-ton crane foundation sectioned in Fig. 23 depends for its stability solely on its weight. It consists of a cast-iron cylinder, 20 ft. diameter by 36 ft. high, built up in segments with flanged bolted joints. This is loaded with concrete to within 5 ft. of the top, the rest of the space being filled up by masonry to form a bed for the crane-post block and the roller path.

The total weight of the cylinder, its contents and the crane itself is 690 tons. If W is the load hanging from the hook at 23 ft. radius that would be required to balance the foundation pull, then, by taking moments about the bottom edge of the cylinder, we have

$$W \times 23 \text{ ft.} = 690 \text{ tons} \times 10 \text{ ft.},$$

therefore

$$W = 300.$$

Thus any weight or force on the crane in excess of 300 tons would overturn the entire foundation.

Before constructing such a foundation the bottom should be examined, and if found lacking in hardness or firmness, it must be piled until solid ground is met with, and the piles will drive no further under the repeated blows of the monkey. In the case shown the bottom happened to be solid rock, and therefore was quite able to resist the pressure, amounting to 2·3 tons per sq. ft. of surface.

Baseplates.—Fig. 24 details a common type of baseplate or surface foundation, as used for a wharf crane with a fixed post and slewing superstructure. It is a circular casting laid on either concrete or masonry or heavy timber, and is bolted down with four long bolts passing through the lugs A. The turned facing B receives the curb ring, and the centre hole C is bored out for the crane post or mast.

On such a casting the stress is constantly changing as the superstructure rotates, the side below the load being compressed and the opposite side tending to lift. Perfect bedding of the baseplate everywhere on its foundation is essential. Though the *bolts* are calculated to resist tension, the casting itself is designed to withstand mixed forces and couples, for which experience is the only safe guide. When such baseplates fail, they generally rupture at or near the central boss, due to the leverage of the load at the post head.

In Fig. 25 we have two views of the base of a fairly large jib crane in vertical section and plan, A being the crane post, B the cheeks or side frames and C the roller path, integral with the curb ring gearing with the slewing pinion. There are four *rollers*, viz., the front one D below the jib and the back one E of smaller diameter, both travelling on the roller path, while the still smaller side rollers F merely serve to steady the crane round the post. In larger cranes the side rollers often run on the path too, though on its flat upper face. The front, back and middle *roller frames* are indicated by the reference letters G, H and J. The cross girder K, connecting the two cheeks, is a combined stretcher and bearing for the shaft of the pinion L engaging with the spur or curb ring C.

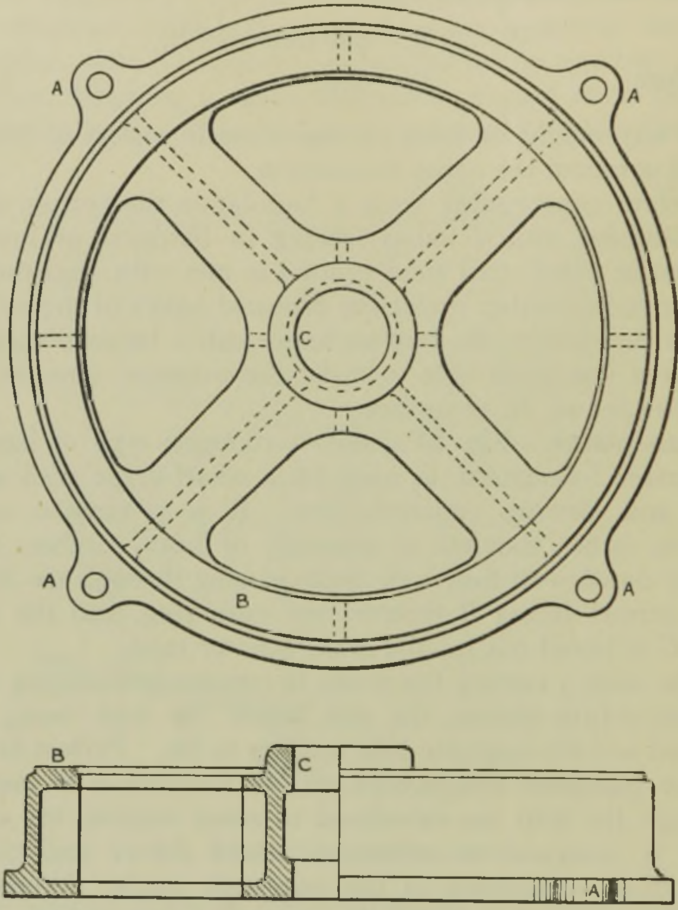


Fig. 24.—Baseplate for Wharf Crane.

The big front roller D takes most of the load. Its turned trunnion ends enter the cast-iron bearings riveted to the steel side frames. The adjoining necks are encircled by the jib feet. The inside of the front roller box G is cored out to take the roller, whose journal runs in brasses fitted into square seatings.

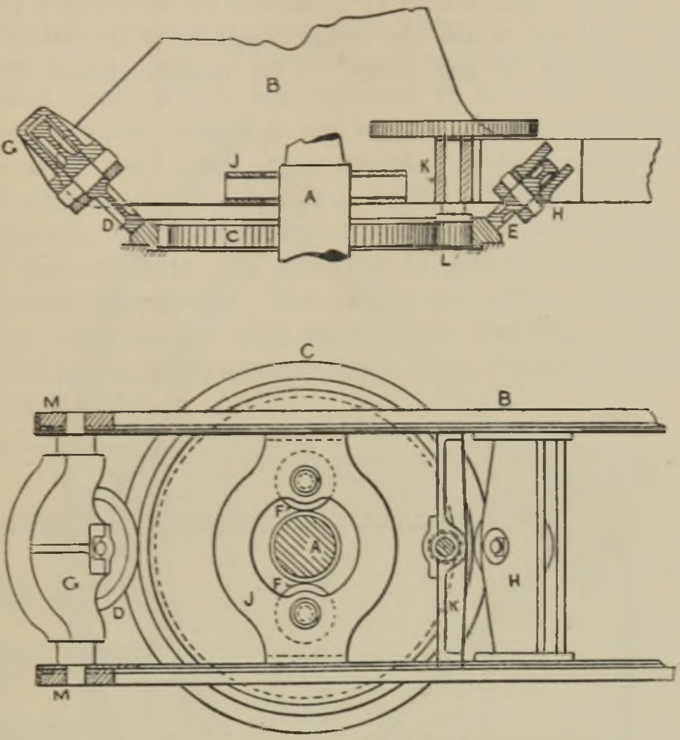


Fig. 25.—Base of Fixed Jib Crane.

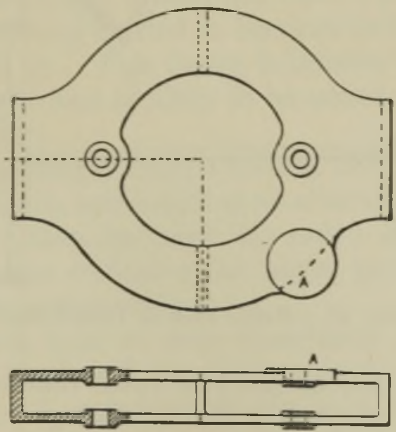


Fig. 26.—Middle Roller Frame.

The back roller frame H is bolted by its flanges between the side frames, while the roller itself runs in either plane bored holes or a top brass. The middle roller frame J

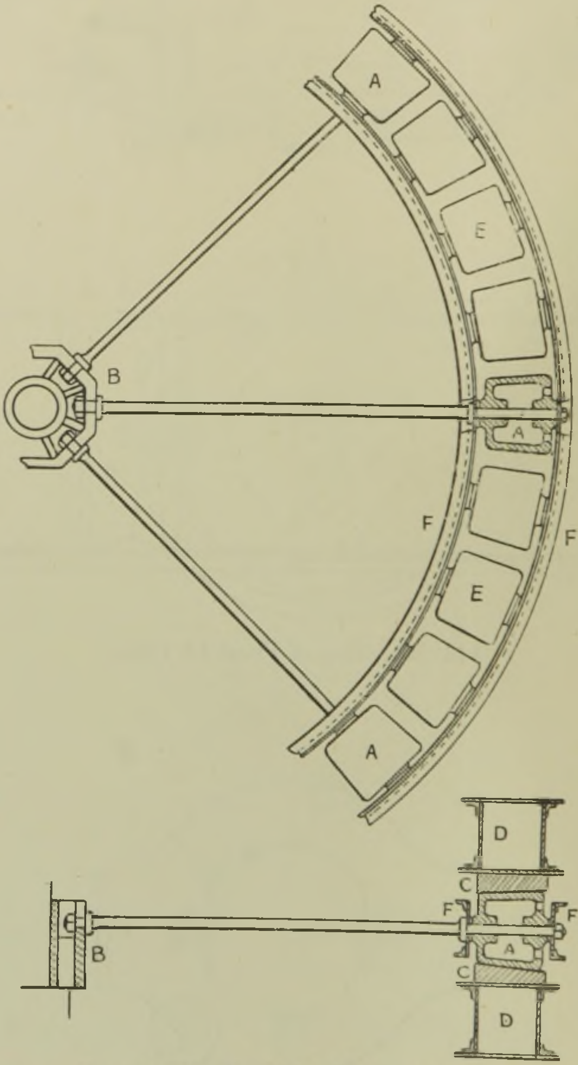


Fig. 27.—Roller Path of Titan Crane.

(detailed in Fig. 26) carries two small rollers, whose pins fit in holes on the centre line of the casting. The facing at A is intended to receive a bearing for the slewing pinion.

In the largest cranes of all, such as Titans, roller frames are omitted, their places being taken by rings of live rollers A, running between the upper and lower roller paths C, as indicated in Fig. 27. The *main rollers* rotate on the ends of the radial rods, which are fastened to a centre casting B. The intermediate rollers E are kept in their proper position by the inner and outer guide rings F. Each *roller path* is formed of a steel bar bent to a circle. It should be turned after bending, but when a large enough lathe or vertical boring mill is not available, the steel bar is planed to a bevel first and curved afterwards. The rollers are either iron or steel castings, cored hollow and trued up in the lathe. But only rollers of large diameter are made thus, those of small size being solid discs.

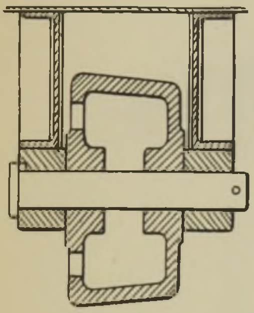


FIG. 28.—Section of Circular Girder and Roller.

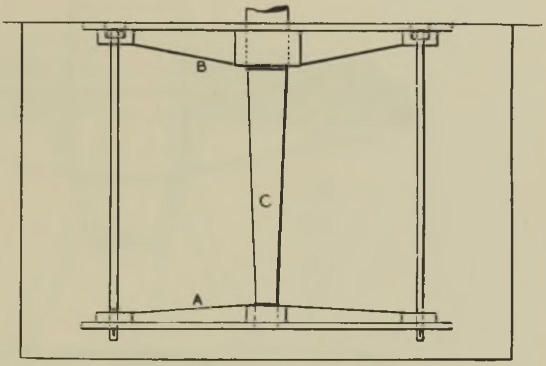


FIG. 29.—Deep Foundation and Post.

Cranes of large size sometimes have a *bottom* roller path only, the rollers being carried in bearings secured to a circular girder, as in Fig. 28. This design is inferior to that of Fig. 27, as the wear on the pins is likely to be severe, but it is cheaper to carry out.

Instead of unflanged conical rollers, tied to the axis of the crane by radius rods, one might as an alternative adopt double-flanged conical rollers and omit the rods ; as is done in supporting the turrets enclosing the heavy guns of battleships, and also in some swing-bridges.

In a common type of deep foundation for a fixed crane (Fig. 29) the baseplate B lies level with the ground, and the foundation plate A is buried deeply in a mass of concrete, the two plates being united by long foundation bolts with cottered ends. Great depth is needed to give the required

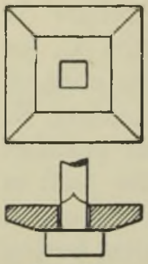


Fig. 30.
Washer-plate.

stability. The crane post C is carried down and stepped into the bottom or foundation plate. The stresses on the latter are severe, and the design is correspondingly strong, with heavy central boss and a web stiffened with deep ribs. Sometimes the bottom plate is omitted and square washer-plates (Fig. 30) substituted. The neck of the bolt is made square to prevent it turning when tightening the nuts at the top.

A standard type of baseplate for jib cranes of moderate size is detailed in Fig. 31, both in plan and cross-

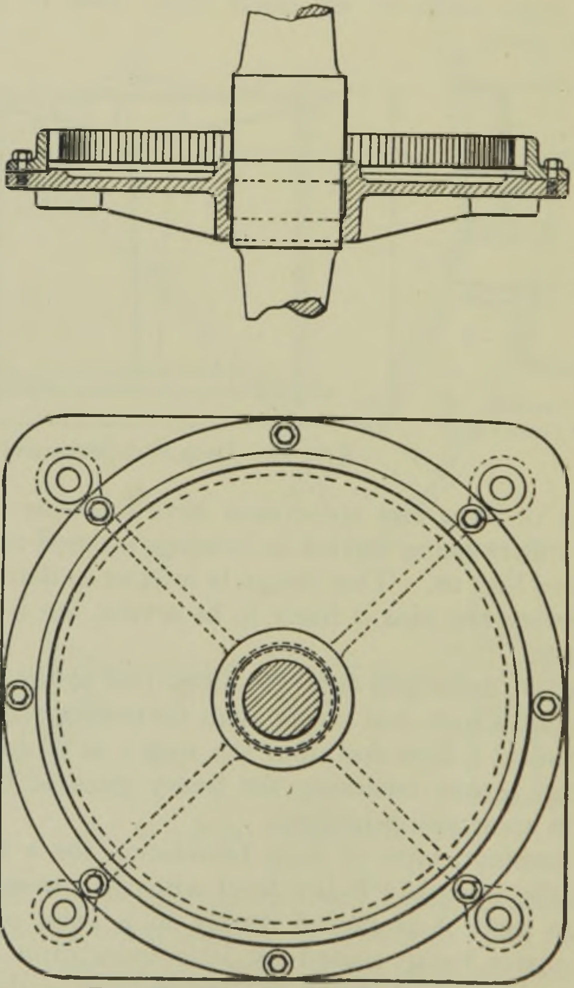


Fig. 31.—Baseplate and Curb Ring.

section, showing clearly the curb ring bolted to it, also part of the crane post. At the corners are seen the recesses for the nuts of the long foundation bolts, strengthened by four ribs, which are firmly bedded in the concrete foundation.

A similar baseplate and curb ring are seen in Fig. 32, but in a very different situation, viz., on shipboard, where it is obvious that neither concrete nor stone foundations can be utilized. Here the foundation goes down to a lower deck, and vertical plates and diagonal bracings give support just below the baseplate. In ships' cranes not exceeding 3 tons in capacity it suffices to bolt the baseplate to the upper deck and carry the crane post in a footstep on the deck beneath, without using any bracings. The foundations of big floating cranes are naturally of more complex design.

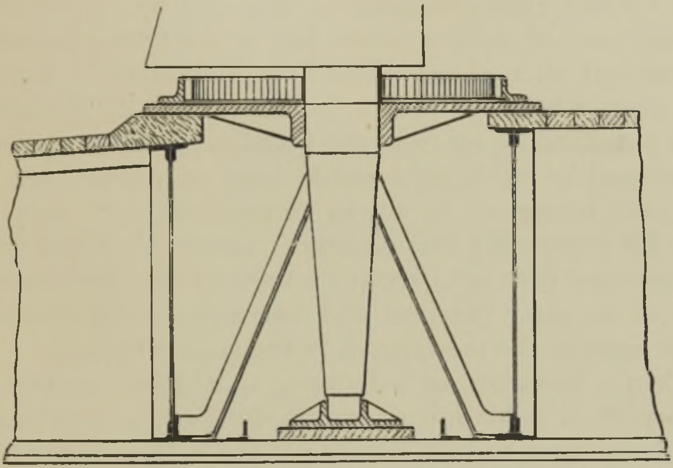


Fig. 32.—Baseplate and Post for Ship Crane.

In the old *Fairbairn type of fixed crane* the jib consists of a plated curved cantilever, which enters the foundation and is extended well below the ground, to carry the bottom pivot pin, resting in a footstep. The curved jib gives ample clearance for bulky loads. The pressure at the ground level is taken by a ring of live rollers running between machined paths.

The foundation for such a crane is expensive, requiring a large mass of concrete or of masonry, also the central port must be hollow and the bottom pivot accessible for inspection and lubrication. The foundation pit is lined with cast-iron plates, and a pump is provided to clear the pit from water.

Though now out of date, at one time Fairbairn cranes enjoyed great favour, being much used as wharf cranes for loading and unloading vessels, and for getting engines and boilers into and out of steamships. They were usually driven by steam engines, the crane carrying its own boiler. But the fact that Fairbairn cranes are costly to make and to support has caused them to become displaced by other designs of crane having greater mobility and other technical features calculated to enhance their economic value.

Functions of Baseplates.—From a general consideration of the various examples given in this chapter, it will be seen that the base of a fixed crane has at least two functions to perform and often three. The first of these is to receive the crane post, which fits into a hole bored in the bedplate, or over a pin standing up from the bedplate, as in many derricks. The second is to form a stable base to prevent the crane from overturning, or to act in conjunction with some other device for preventing this disaster. Lastly, the third function of a jib-crane base is to receive a toothed ring for slewing the crane, or to carry brackets and bearings for the operation of certain parts of the mechanism in the superstructure.

When a baseplate or a footstep is laid on concrete or on masonry, it is held down securely by long bolts, which pass through the mass and are retained at the bottom of the foundation by their heads against broad washer-plates. Thus before a crane could overturn, it would have to either break the bolts or pull up the concrete bodily.

Though a bed may never get pulled up, a bedplate may in rare cases become fractured by the bending stresses imposed by lifting an excessive load at a long radius and by shocks incidental to hoisting and lowering. Hence bedplates should be deeply ribbed, and made considerably deeper next to the central boss than at the bosses for the holding-down bolts.

A BIG FIXED CRANE

It is both opportune and instructive to compare the above relatively small crane bases with the foundations needed

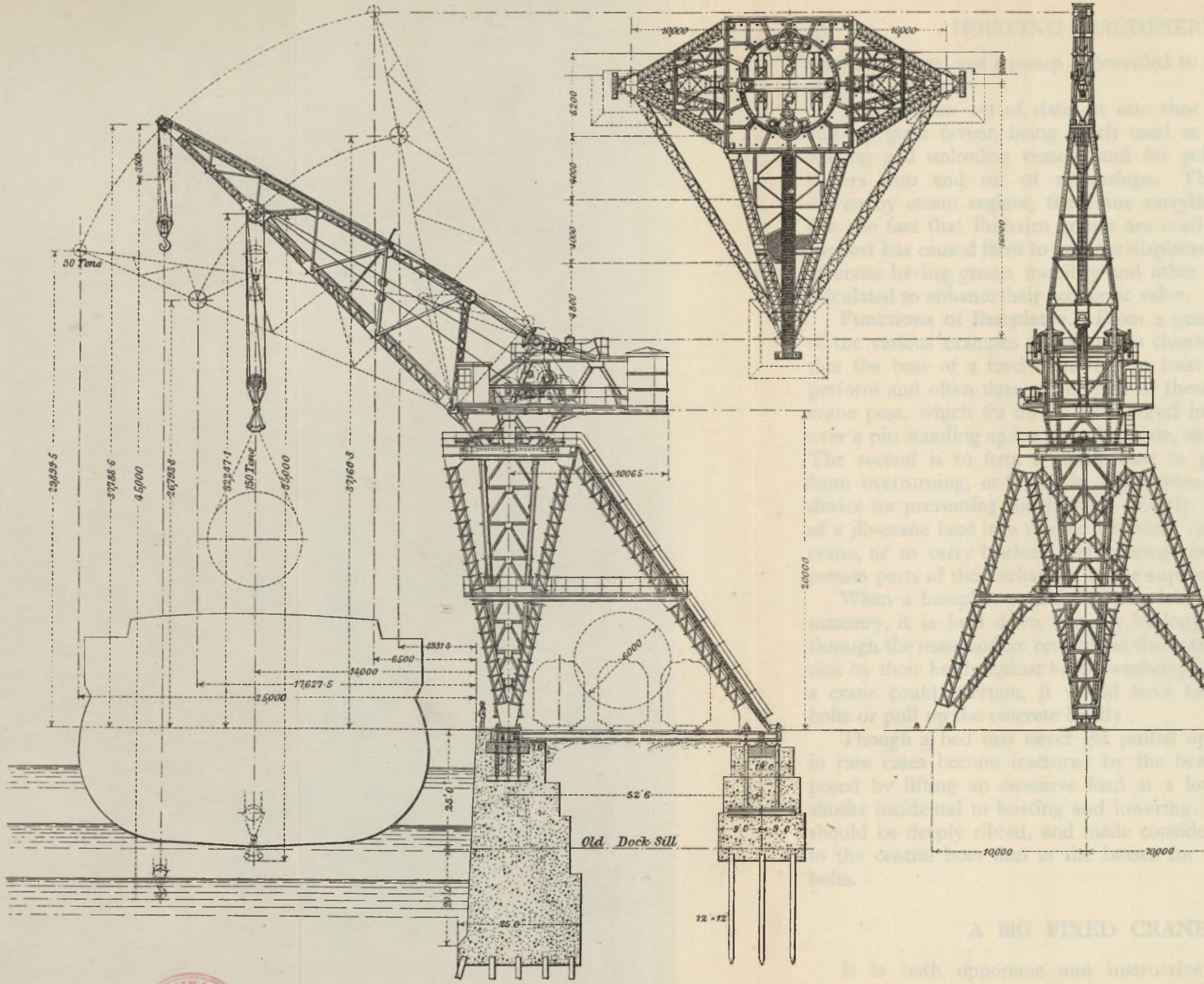


FIG. 33.—150-ton Derricking Crane.

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for a really big crane, such as the 150-ton derricking crane illustrated in Fig. 33, taken from *Engineering* of June 7th, 1907, where this fine crane was fully described. It was made by the German firm of Bechem & Keetman of Duisburg, though erected at Birkenhead, in the yard of the Tranmere Bay Development Co. Ltd., on the quay of their dock. The weight of the constructional steelwork in the crane is 305 tons, and the counterweight alone weighs 162 tons.

In this crane the jib is luffed or derricked by rotating right and left hand screws, a method of luffing that is still favoured and specified by the British Admiralty in heavy cranes of recent construction, as being safer than steel ropes. The maximum load is 150 tons at 28 ft. radius or 50 tons at 88 ft. radius, the overturning moments being 4200 and 4400 ton-ft. respectively.[1]

From the drawing it will be observed that the front concrete foundation along the edge of the quay is some 50 ft. deep by 25 ft. wide at the bottom, and rests on a piled subsoil. The rear foundation also rests on piles 12 in. square and over 20 ft. long. The back leg is held down by long foundation bolts and grillage joists loaded with a mass of concrete 18 ft. square, forming a firm anchorage. The fixed supporting frame rests on three feet, which are tied together by lattice steel sleepers just below the ground level and above the massive foundation blocks.

Enclosed within the supporting structure is the revolving upper part carrying the hoisting machinery proper. The top of the supporting frame guides the upper part of the revolving tapered post, which widens out to carry the mechanism.

The revolving load is carried entirely by the centre foundation, while the suspended load produces a tipping moment or couple of which one force acts at the foot of the post and the other force acts at the pressure ring at the top of the supporting frame. In the centre foundation there is a special footstep

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[1] I prefer to use consistently the ton-foot (or else the pound-inch) as the unit of measurement of moments and torques, which are statical couples. Also, I like to reserve the conventional foot-pound (or else the foot-ton) as the unit of work or mechanical energy. This is a totally different dynamical quantity, involving actual *motion*, or force continuously exerted throughout a distance, instead of being simply the product of a force into a fixed arm or radius.

bearing, working constantly in oil, to take the thrust due to the direct vertical load. The connection between the post and this thrust bearing is so designed that no serious results would follow in case the foundation should settle somewhat.

At the upper part of the supporting structure the tipping force is taken by a roller bearing, there being six guide rollers around the post, running on a circular rail fastened to the inside of the fixed guide or pressure ring. The slewing pinions are in duplicate, engaging with a fixed pin-type ring, not a spur-toothed rack.

On the forward part of the upper or main platform is placed the driver's cabin, where the control switchboard is fitted and where the outreach of the jib can be read from a pointer working over a dial. The series-wound motors run on direct current of 500 volts pressure.

Speeds and Powers.—This is not a high-speed crane, and for the sake of subsequent comparison the working speeds will be given here. The two motors of 12·5 H.P. take 6 min. to slew the crane one complete revolution about its vertical axis. One motor of 57 H.P. takes from 10 to 15 min. to luff or derrick the loaded jib about its horizontal axis from the greatest to the least radius of the hook. One 110 H.P. motor hoists the full load of 150 tons on the heavy hook at the rate of 5 ft. per min., and a load of 50 tons on a smaller auxiliary hook at the rate of 20 ft. per min. The calculated gravity powers at these speeds are 74 and 68 H.P. respectively. The empty big hook is lifted at a speed of 8 ft. per min. and the small hook at 30 ft. per min. It is characteristic of the series-wound motors used on this crane that they run faster at light loads and so adjust their speed more or less automatically to suit the load.

The design of this interesting fixed crane is claimed to possess the following merits :—

1. Having the crane post placed quite close to the quay wall increases the *effective* outreach of the jib. Also, the tipping moment is lessened thereby, so that the pull at the three foundation points is reduced to the lowest possible, resulting in smaller foundation blocks.

2. The supporting frame does not obstruct general traffic under the crane, on account of its open construction. It gives room for three full-gauge railway tracks underneath.

3. The three-legged support admits of exact calculation of the stresses, and especially of the forces acting on the foundations, thus avoiding waste of material.

4. Any slight one-sided settlement of the foundations is not seriously detrimental.

5. The driving gears are all arranged to be readily accessible, and spare parts can be fitted without difficulty.

6. The crane is of great utility when erecting work, because the jib is narrow and can easily enter between the masts and funnels of steamships.

7. The crane is independent of the height of ships' superstructures, because, when the jib is luffed to its minimum radius, it revolves quite clear.

8. Small movements in any direction can be made with ease and exactness, particularly when fitting machinery or placing engine parts in position.

CHAPTER V

PORTABLE AND LOCOMOTIVE JIB CRANES

A PORTABLE crane is one mounted on wheels and so capable of being easily moved about by horse traction, petrol tractor or otherwise, but it is not self-propelled. In this respect it differs from a locomotive crane, which carries its own means of propulsion. The superior mobility of locomotive cranes renders them of far more general utility than simple portable cranes. Movable cranes are often of constant radius, the lack of derricking power being less objectionable here than in the case of *fixed* cranes, since the position of the truck can be adjusted to suit requirements.

Originally locomotive steam cranes were designed for travelling on a railway track and used solely for railway work, but they were soon adapted for general work, including goods handling. Sufficient power is available for hauling and shunting wagons at a slow pace in factory yards. Moreover, such cranes are often equipped with *grabs* for handling bulk materials such as coal, gravel and sand. They can then be utilized for unloading barges alongside of a canal or river wharf, as well as by contractors engaged on civil engineering works involving considerable excavation. (See Plate 33).

Hand Cranes.—Simple hand cranes are still used for occasional service, which would not pay for a more expensive crane, despite the increasing application of steam, oil and electricity. The earliest examples were practically cranes of the fixed type but mounted on a four-wheeled truck. These are still retained in many country districts and provincial works, including some railway sidings. Being portable, they must be *balanced* cranes, since a counterbalance is the only device by which the loaded crane can be rendered stable.

We meet with much variation in the methods of balancing movable cranes. Usually the balance weight is fixed at a constant radius, though many hand cranes have been fitted with rollers A by which the balance boxes and their contained weights can be moved along the tail of the crane to various radii to suit variable loads, as seen in the example outlined in Fig. 34, which has a cranked jib of fixed radius.

In many cases cranes are counterbalanced with a number of loose weights which can be loaded by hand. A cruder device is to make a ballast box, fit it on the tail of the crane and load it with stone. But cast weights, uniform in size and shape, are better supplied and loaded either into a box in hand cranes, or under the footplate in steam and electric cranes. The centre post of the crane takes the unbalanced load.

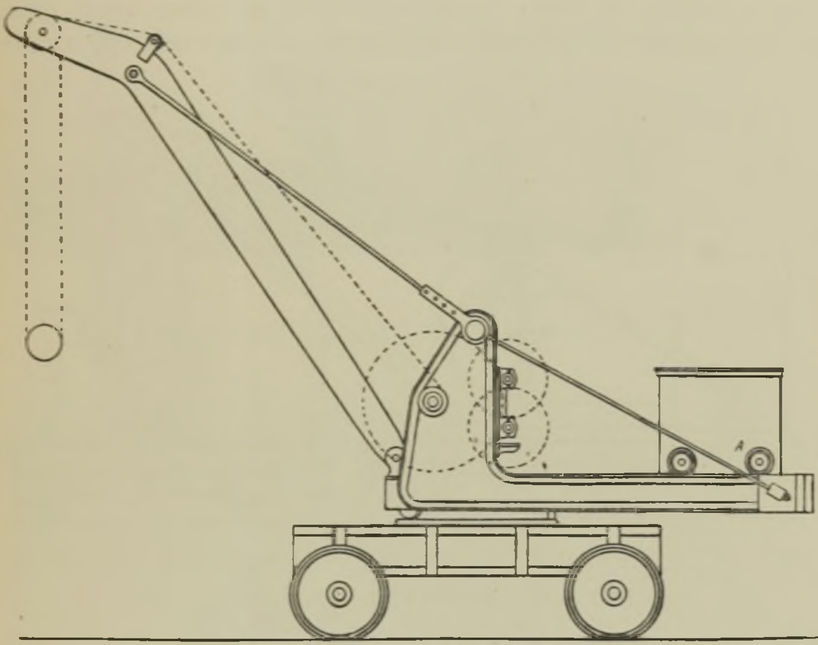


Fig. 34.—Portable Hand Crane.

Balance boxes are made in various ways: either in cast iron in one piece, or with separate cast-iron plates bolted together, or in steel plates riveted or welded to angles. The first two are suitable for common cranes, the last for breakdown cranes used on permanent way.

An objection to putting an excessive amount of balance on a crane is the great risk of causing oversetting. When the crane is not working it is sufficiently stable. But if a load is lowered and dropped, and disengaged suddenly, as in tipping from a bucket, the reaction is very likely to cause the crane to tip over backwards, an accident which has occurred on rare occasions. The danger is greatest when the crane is lifting across the track, or diagonally. Sometimes so much balance is required that wing plates have to be fitted, standing out to right and left, wider than the crane itself, and loaded with weights.

A common type of portable hand crane is shown in Fig. 35. The dimensions refer to a crane of 3 tons lifting capacity. When raising a heavy load the use of blocking joists gives greater stability. The tail balance box is best made adjustable.

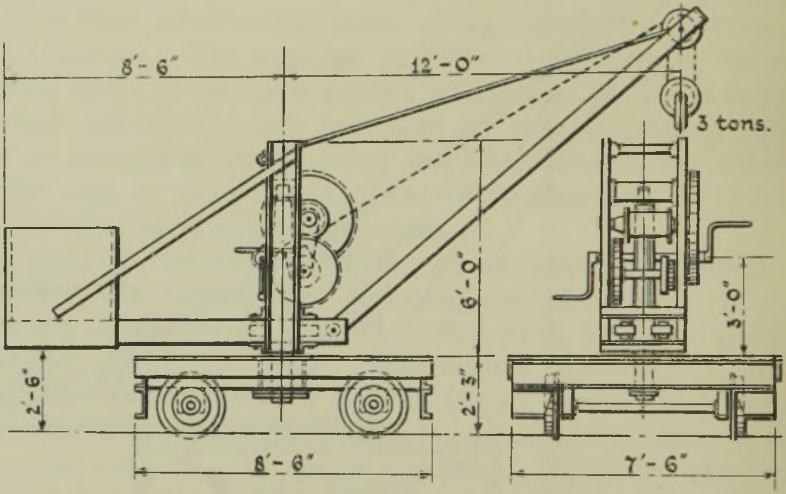
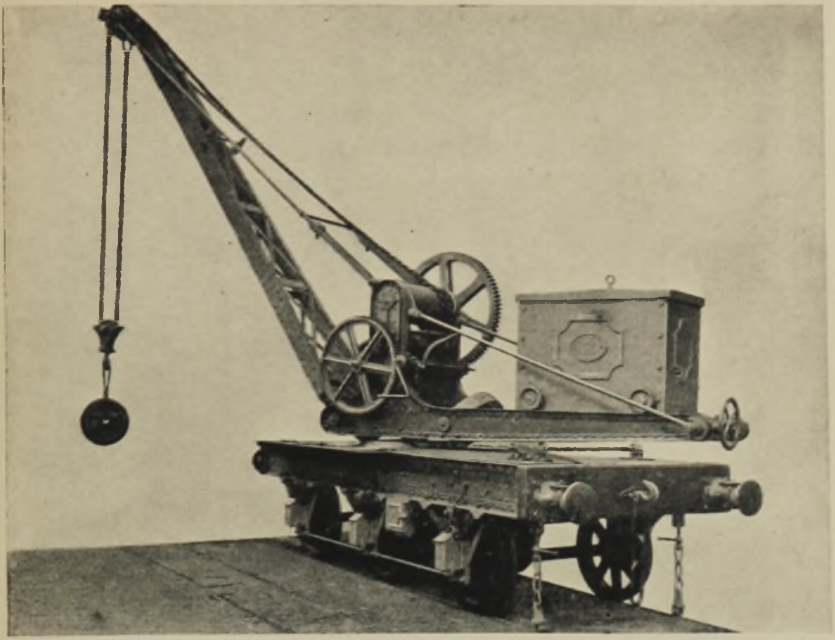


Fig. 35.—3-ton Typical Hand Crane.

Before the box is racked out one must take care to have the blocking joists in position, lest the crane should become unstable when slewed round with the jib across the truck. In the smaller cranes slewing gear is not fitted and the hoisting gear is of single purchase.

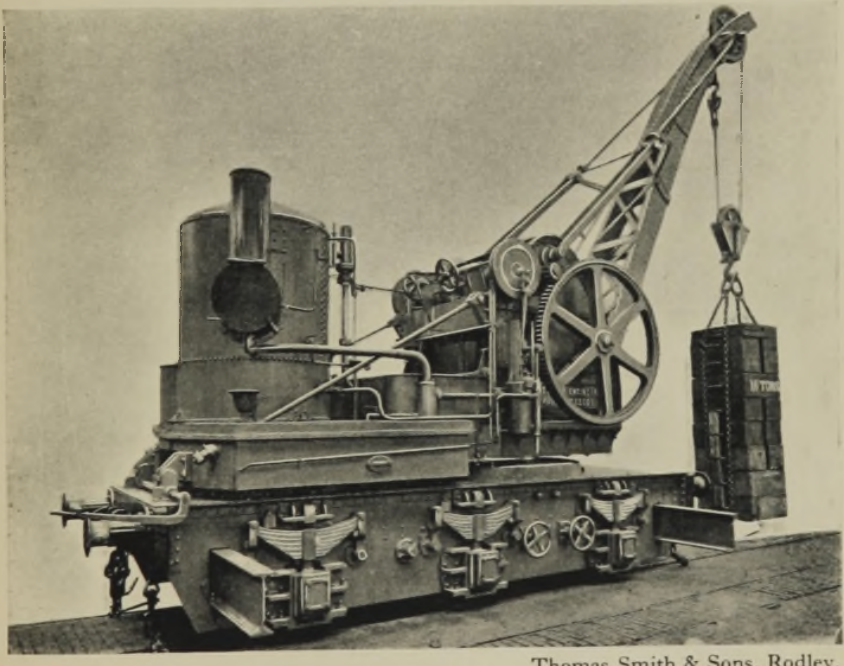
For hand cranes of over 2 tons capacity it is usual to fit double-purchase gear, having a sliding handle shaft with two pinions of different sizes, but when lifting light loads the single gear only is used, to obtain a quicker lift. Then the brake and the ratchet wheel are fitted to the second motion shaft, which is always in gear with the barrel shaft.

In the smaller sizes of portable crane the truck or carriage is constructed of cast iron, while in the larger sizes it is built



Thomas Smith & Sons, Rodley.

Permanent-way Hand-balance Crane.



Thomas Smith & Sons, Rodley.

16-ton Permanent-way Steam Crane.

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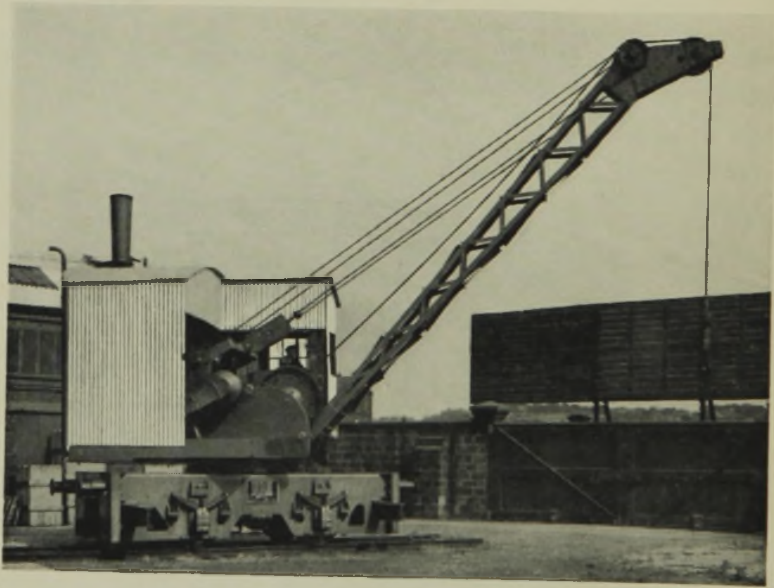
Joseph Booth & Bros.

STEAM DERRICK CRANE.



Joseph Booth & Bros.

10-TON LOCOMOTIVE STEAM CRANE.

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up of steel channels. Hand travelling gear is not fitted, except in cranes of over 5 tons capacity.

In the case of a crane designed for light railways work, before it can be coupled to permanent-way rolling stock it must be provided with axle-boxes, springs and couplings. Moreover, its travelling gear must be disengaged and the outriggers made to slide in, so as to pass the standard running gauge.

POWER CRANES

For a long time two types of portable steam jib cranes have been made extensively, viz., (1) the vertical engine type, fitted with a long centre post, and (2) the horizontal engine type, fitted with a short centre pin. The latter crane has a very different appearance from the former, the entire arrangement of the framework and gearing being changed, though the jibs are similar.

In locomotive cranes proper a separate pair of engines is used for travelling, but as a rule the hoisting engines also drive the truck in the ordinary contractor's steam crane, when a special set of travelling gear has to be introduced. Starting from the engine shaft, the operating gears are placed above the centre post, down which a shaft passes (Fig. 36), with bevel wheels at the bottom, and thence through bevel wheels on one or both of the travelling axles, as seen in Fig. 37.

In the steel centre post shown in Fig. 36, the hole for the passage of the vertical shaft is bored out of the solid, and the ends are bushed with gun-metal. The post is fastened to the truck partly by making a press fit and partly by keys.

Truck Details.—There are various designs of trucks. In some cranes of low and moderate power, cast iron is used wholly for framing, including its centre boss, roller path and axle bearings. But in better-class cranes the framing is steel-plated, with the centre only of cast iron, while the axle bearings are cast and bolted on. Many trucks are made to permanent way requirements, with axle boxes, springs and buffers. Others are made with two sets of wheels in order to adapt the crane to different gauges. Some trucks are constructed with two sets of wheels at right angles for cross traversing, as indicated in Fig. 38.

A truck frame made wholly of cast iron and suitable for cranes up to 5 tons capacity of standard gauge, viz., 4 ft. $8\frac{1}{2}$ in., is shown in Fig. 39. The bed is in effect a beam or girder, supported on the axles at the centres *a*, with overhanging ends. The bottom flange is in tension, while the rather

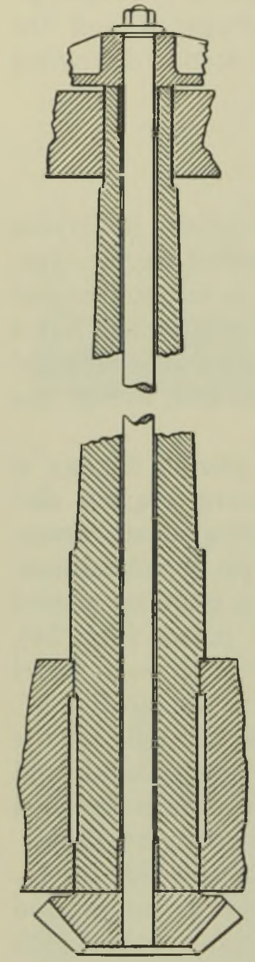
Fig. 36.—Centre Post and Shaft.

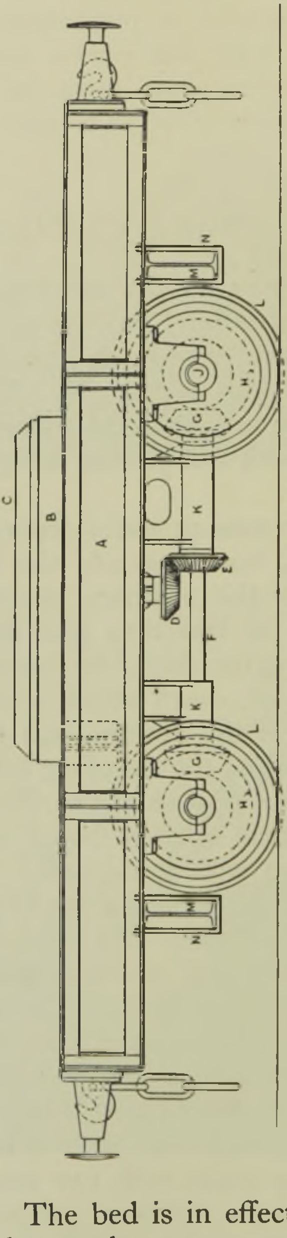

Fig. 37.—Steel-plated Truck.

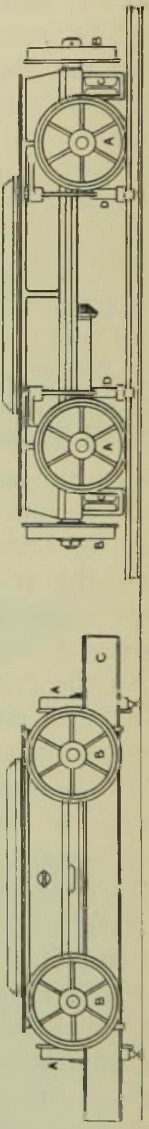

Fig. 38.—Eight-wheel Cast-iron Truck.

thinner top flange is in compression. The facing on which the curb ring is bolted is marked A and the lower facings on which brackets are bolted to carry the shafts for the travelling gears are marked B. The axle bearings C are cast with the bed and fitted with cast-iron caps. The ribs cast above the bearings afford them local support, while the brackets at the ends of the bed are provided in order to support the bottom flanges when blocking girders are being used.

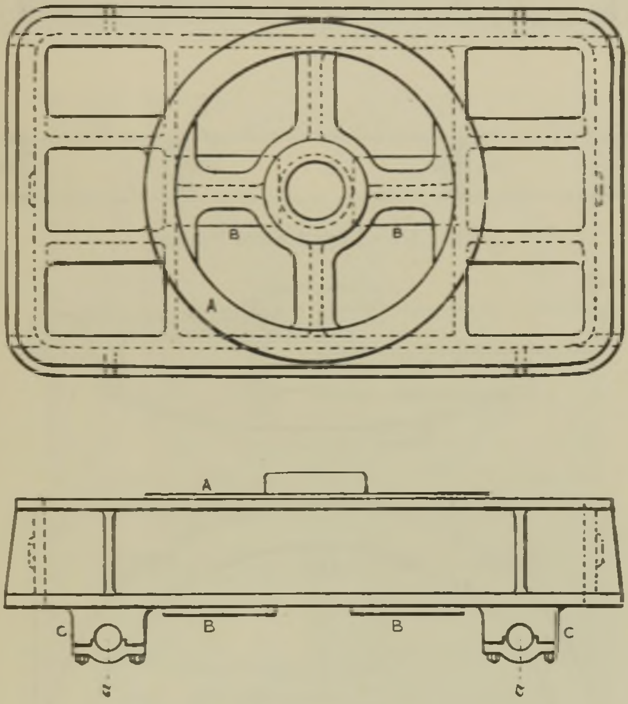

FIG. 39.—Four-wheel Truck Frame.

Fig. 40 shows a built-up steel truck frame as it leaves the plating shop in readiness to receive its cast-iron fittings. This is typical of forms of the same general design, in which details are modified. Here the sides AA are rolled steel joists, but in heavy cranes, though a similar section is retained, the sides are built up from plates and angles. A bed of this kind is seen in Fig. 37. Sometimes the section is that of a channel, either rolled or built up, like the ends BB in Fig. 40. Joists CC connect the sides AA with angle cleats *aa* some distance away from the ends, and in positions which are fixed

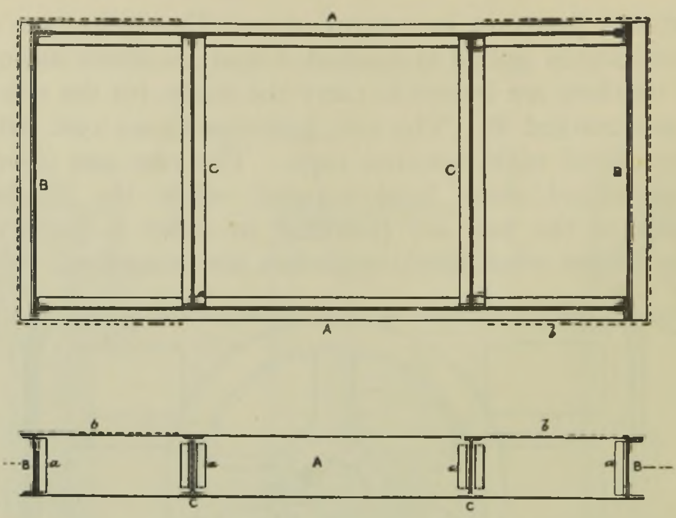

Fig. 40.—Plated Steel Frame.

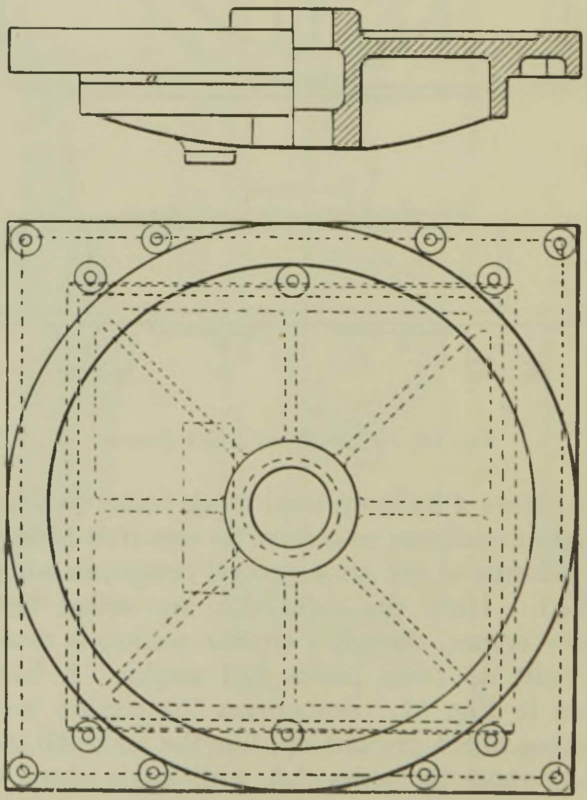

Fig. 41.—Centre Casting of Truck.

by the centre casting. Such a frame would need bracing but for the fact that the centre casting makes it very rigid. This casting fits upon the top flange and between the sides AA and the cross girders CC. The dotted outlines at *bb* denote cover plates, covering those openings not occupied by the centre casting. The whole of this steel framing is either riveted together or is secured by welding.

In the latest designs of truck frames, castings have been largely displaced by fabricated details, built up from steel plates and standard sections electrically welded together. A modern example of such a truck is seen in the 10-ton locomotive steam crane made by Joseph Booth & Bros. of Rodley, as depicted on Plate 6. In engineering works there is an enormous demand for the special electrodes consumed in the process of electric fusion welding, and their manufacture has become of recent years a very profitable industry ; whereas rivets are now in relatively small request. Cutting and welding processes by means of the oxy-acetylene flame are also much practised nowadays in crane shops.

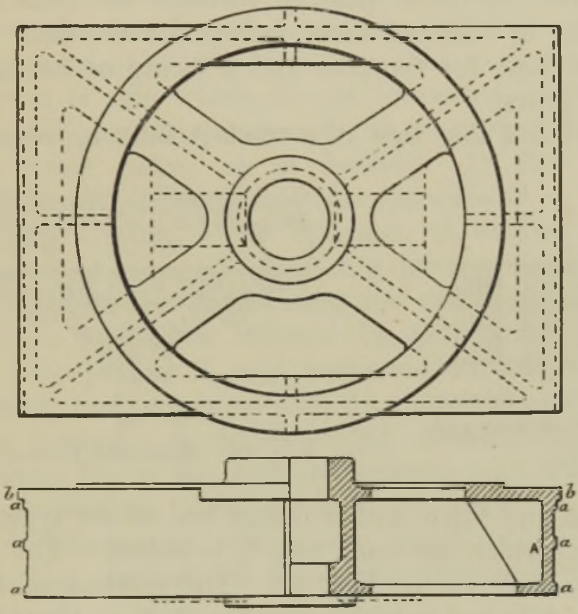

FIG. 42.—Alternative Centre Casting.

Two typical forms of centre castings are detailed in Figs. 41 and 42. The former is designed for bolting on a steel truck frame like that illustrated in Fig. 40, its relation to the plated work being seen in Fig. 37. It is secured by bolts passing down through the holes seen in the plan view, while a fillet *a* against each edge fits closely to the inner edges of the side girders.

The other design of centre casting or bedplate, however, as shown in Fig. 42, fits by the strips *a* down the entire depth of the girders, which in this case are of channel section. Here the top flange is reduced to a mere fillet *b*, whose edge fits on the top edge of the [section. The frame is secured to the plated work by bolts passing through its sides A. Both these types of bedplate carry facings for the curb ring, also the centre boss for the post and a facing or facings for the travelling gears.

Fig. 37 is a side view of a truck A built up of steel plates and angles and fitted with a centre bed of the type shown in Fig. 41, to which the curb ring C is bolted. The section of the latter is shown in Fig. 43. The method of fitting the curb ring to its bed is with a circular check or shoulder turned to fit a corresponding shoulder on the face of the bed.

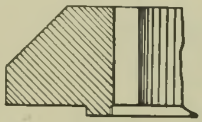

Fig. 43.—Section of Curb Ring and Path.

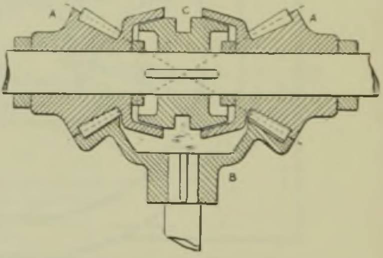

Fig. 44.—Reversing Cone-clutch.

Though many curb rings are bolted down to the bed, one firm of crane makers conceived the idea of omitting the bolts altogether, leaving the fitting in other respects the same. It was found that the teeth were then less liable to fracture under the stress of sudden starting and stopping, while the frictional grip of the ring was sufficient to prevent it from slipping under ordinary conditions of working. The bevelled face of the curb ring is turned to form a path for the rollers upon which the superstructure rotates.

In the case of the steel-plated truck (Fig. 37) the bevel gears transmit the travelling motion derived from the upper part of the crane by a vertical shaft passing down the hollow centre post and carrying the mitre wheel D upon its lower end. This drives the wheel E and the shaft F, to which are keyed the two bevel pinions G, each driving its own wheel H, keyed to the right and left hand axles J. The shaft F is carried in the bearings KK, bolted to facing pieces on the bottom of the centre casting. On the axles the four single-tyred wheels L are keyed. The blocking girders MM are supported in the stirrups NN, while buffers, drawhooks and chains complete the truck.

Fig. 38 shows a cast-iron truck fitted with two sets of wheels, viz., the regular set A and a special cross-over set B, the latter being used only when the crane has to be transported to another set of rails which are not connected by turntables. The cross rails are laid temporarily in place over the others, the crane being jacked up or lowered. In this example, blocking girders C are fitted and also rail clips D.

Reversing Clutch.—The direction of motion of bevel wheels has to be reversed when they govern the lifting and lowering of loads, also the slewing and travelling motions of cranes. This reversal is effected by the device shown in Fig. 44. Two pinions A with bell-mouthed ends run freely on their shaft, each engaging with the crown wheel B. They should be bushed. A double-ended cone-clutch C slides along a feather key in the shaft and engages with either of the pinions at pleasure, thus driving the wheel by friction. Reversal is effected by sliding the clutch in the opposite direction. Jaw clutches are a common alternative to friction clutches.

Alternative Design of Frame.—One must here digress somewhat to point out that in the design of portable steam jib cranes of the low type driven by horizontal engines, and occasionally termed *horizontal cranes*, the frames are considerably reduced in height and are cast in one piece with the roller frames, except in the larger cranes. The alteration in height affects the design further, because, by setting the engines horizontally and bringing the gears low down, it becomes necessary to lengthen the superstructure at the rear in order to receive the engines and their connections.

Such a cast-iron frame for a horizontal steam jib crane is seen in Figs. 45 and 46 in elevation, plan and cross section. Here we

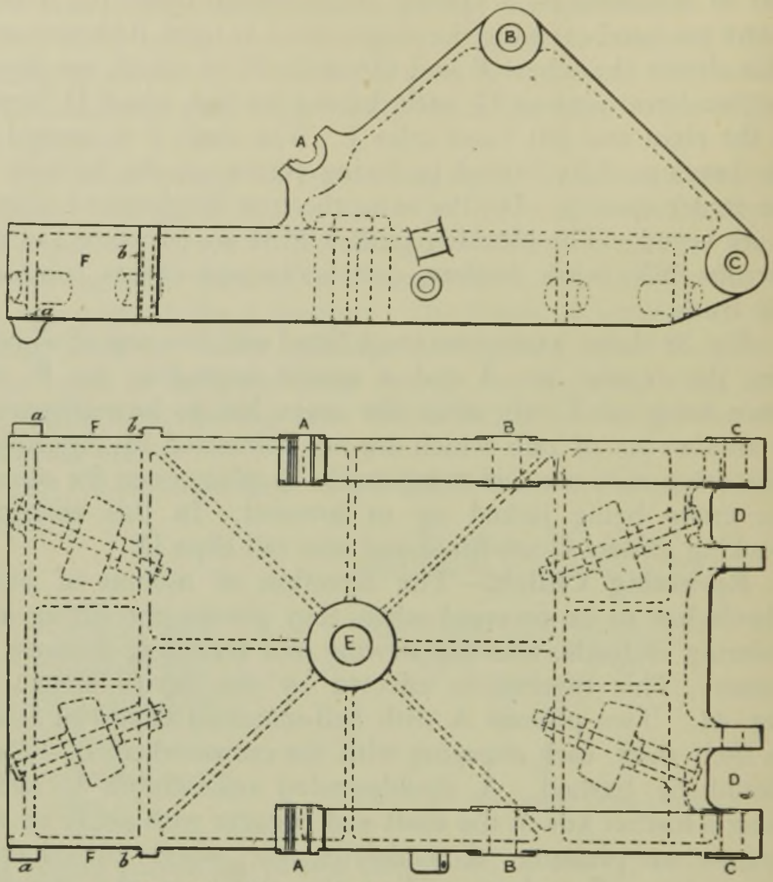

FIG. 45.—Frame for Horizontal Steam Crane.

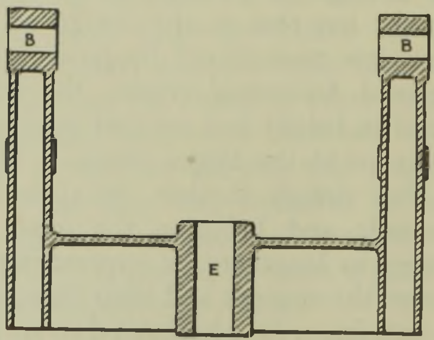

FIG. 46.—Cross Section of Cast-iron Frame.

have a cored-out bed with which the side frames or ‘ cheeks ’ are either cast integral or bolted on. These cheeks carrying the shafts have sometimes been ribbed only, as indicated in the plan view (Fig. 45), but in better designs they are cored out, leaving smooth unribbed faces on both sides. Some of the designs in this class of crane are very neat.

In Figs. 45 and 46 A is the engine shaft bearing and B that for the barrel shaft, while C is the bearing for the pin which carries the foot of the jib. The jib feet fit between the spaces DD. The superstructure revolves around a pin in the hole E of the central boss. The outside faces FF receive the tail girders, which rest on the lugs *a* and come up against the abutment strips *b*. The frame runs on the four conical rollers seen dotted in the plan view.

Side Frames and Stretchers.—As regards the cheeks or side frames of the high or *vertical* type of portable jib crane, these important details are built with some slight resemblance to the shape of an A stand, but much modified, ranging in height from 4 to 8 ft. and from ½ to 1¼ in. in the thickness of the web. They are ribbed either on the outside only or on both sides, at pleasure. The bearings are usually of the divided type and fitted with brasses.

The side frames are used in conjunction with a central post, and are kept at the proper distance apart by stretchers or cross girders. The latter details also fulfil other functions, as that of forming roller frames for slewing the entire superstructure around the post, as well as acting as jib sockets and as centre post heads, thus taking and transmitting the load of the revolving superstructure to the post. It is seldom that a simple stretcher is fitted without utilizing it also for some other purpose, even if only to carry a boss for a lever.

Facings are cast on the inner sides of the cheeks to receive these stretchers, the ends of the latter being planed, while turned and fitted bolts unite them in one rigid framework which rotates round the centre post.

From the point of view of workmanship it is usual to make all the stretchers for a crane of the same exact length, and their facings on the frames all of the same height. Then the stretchers are planed in a row at one operation, while the facings on the cheeks are planed at one setting of the tool, in another operation, so that no resetting of the work or of the tools is needed.

The cheek for a steam crane of the high type with nearly vertical engine is detailed in Fig. 47, the cylinder foot being bolted to the facings A. The bearing B receives the engine shaft and C that for the hoisting barrel shaft. The worm wheel and barrel used for derricking are carried by a shaft at D. At E is the anchorage of the rear tie-rods coming to the tail of the crane, while F is the bearing for the front roller frame over the curb ring.

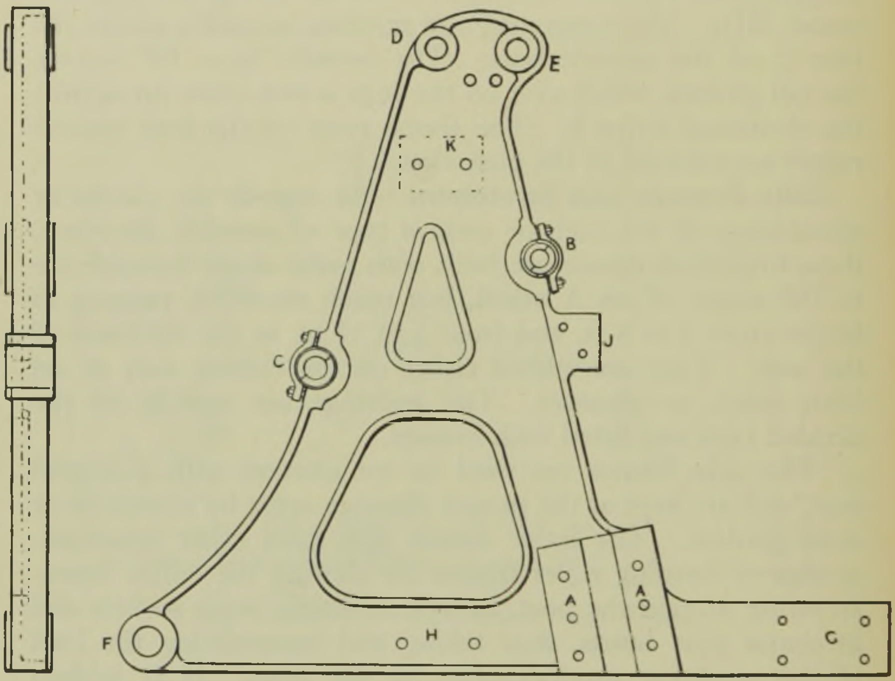

Fig. 47.—Cheek for a Steam Crane.

There are several stretchers or cross girders bolted between the cheeks, the one at G carrying the back roll and that at H the two centre rolls. At J, half-way up, is secured a girder from which the engine shaft clutches and gears are operated. Placed near the top at K is another stretcher which receives the top of the centre post and the anchorage of the luffing chains. The holes for the bolts securing these various cross girders to the cheek are indicated on the drawing.

Certain parts of these frames or cheeks are severely stressed, those most liable to fracture being the upper part of the frame around the tie-rod connection and the front lower part which receives the pressure of the front roller. Several fractures of these two parts have been observed. A good plan is to strengthen the metal over these areas, making the casting, say, $\frac{1}{4}$ in. thicker there than elsewhere, and shaving it down to merge gradually into the general thickness. Another part that is stressed severely is the area around the barrel shaft, due to the direct pull of the load.

Horizontal Portable Cranes.—In the horizontal type of portable steam crane the framework carrying the engines and gearing is not formed of cheeks bolted together with stretchers, as in the vertical design, but is usually made in one casting and is termed the revolving bed, because it turns round the centre pivot or dwarf post, being thus distinguished from the truck or base, which does not revolve. As shown in Fig. 45, this revolving bed is a hollow casting, with bearings for the engine shaft and gearing, also axles and facings for the attachment of the engines.

Steel girders are bolted to the sides of the bed, extending beyond the hinder end to carry the footplate and the boiler. A heavy cast-iron tank is bolted between the girders to hold the feed water and to serve as a balance weight.

The engines comprise a pair of high-pressure cylinders, sometimes cast separately and sometimes together. The cylinder guides and steam chests are made in one, and cast with a foot for bolting down to the bed. Link reversing motion is applied to each cylinder.

The load is hoisted through spur gearing, the pinion being on the engine shaft, and it is slid out of engagement when lowering on the brake. This gear is similar to that adopted on the vertical type of crane.

The slewing of the load is done through bevel wheels, fitted with reversible friction cones in order to be able to slew in either direction without stopping and reversing the engines. The motion is transmitted through intermediate gears to the curb ring on the truck below. By reversing the bevels the direction of rotation of the revolving bed is reversed. It turns on four rollers, two at the front and two behind.

The whole bed is kept from lifting by means of a dwarf centre post or pin passing through the centre of the truck below and through a hole bored in the centre of the revolving bed, in which it fits with a solid forged head on a shoulder with friction washers. The massive nut securing it at the lower end is tightened up in opposition to the bolt head just enough to keep the revolving structure well down on the roller path.

The boiler and the water tank form sufficient balance weight in cranes with short jibs, but in those with long jibs a special balance plate is cast and bolted underneath the tank, loose weights being laid upon this plate.

Many portable steam cranes are made of from 2 to 3 tons capacity for regularly lifting loads of from 1½ to 2 tons. Some of these, used for coaling, have jibs of exceptionally long radius. They lift in single gear, that is, with the pinion gearing with the barrel wheel keyed on the engine crankshaft. The barrels are also made of larger diameter than those of the average class of crane. Loads of 5 to 10 tons are hoisted on two falls of wire rope and 12 to 15 tons on three falls of rope.

Crane Engines and Boilers.—Steam has been used for driving every type of crane made, from the lightest to the most powerful. It is so easy to put an engine on any crane, while a boiler is an excellent counterbalance to a jib. It has been the practice in crane works to have only a few standard types and sizes of engines and boilers, making these do duty for nearly the entire range of steam cranes of all classes, and designing the gearing to suit the requirements.

Crane engines and boilers are of simple type. The cylinders are bolted to side frames or to footplates or to beds, according to the class of crane. The steam works expansively with a single valve, set with a lap giving admission during about seven-tenths of the stroke, and exhausts into the atmosphere. It is advisable to pass the exhaust steam through a simple type of separator to avoid the nuisance of having condensed steam or water blown out of the chimney on to the crane driver.

The nature of the service is not such as to admit of any of the usual refinements common to high-class stationary engines. The service is hard, an enormous amount of steam being needed during the performance of maximum duty, while the service is intermittent in character. Hard firing is often required between heavy lifts to keep up the steam pressure.

Taking the capacity of portable cranes as ranging from 2 to 15 tons, and the working radius as 16 ft., the horizontal cylinders range from about 6 in. bore by 8 in. stroke to 9 in. bore by 12 in. stroke.

The boiler employed is usually of the vertical type, as being easily fired and kept in working order. The cross tubes vary from one in the smallest to three in the largest boilers. The crowns are stayed, fire bars are either cast or wrought, and the shell is generally lagged with either wood or sheet iron, so as to lessen the radiation and waste of fuel.

Heating Surface of Boilers.—Using the ordinary cross-tube type of vertical boiler, a normal provision of heating surface in cranes burning *coal* is given in the table below. When *wood* is the fuel burnt, however, the boilers should have fireboxes of, say, 30 per cent. larger capacity.

Capacity of Crane	For Locomotive Cranes	For Shunting or Grabbing Cranes
Tons	Sq. ft.	Sq. ft.
3	55	75
5	75	95
7	80	100
10	95	130
12	110	150
15	130	170

Crane boilers range in size from about 3 ft. diameter by 6 ft. 9 in. high to about 4 ft. 6 in. diameter by 9 ft. high. They are designed and constructed to have a factor of safety of at least *five* at the intended safety-valve load (usually 100 lb. per sq. in.). On completion they are tested hydraulically to a pressure of 1½ times the safety-valve load.

Safety valves are of the direct spring-loaded type and provided with a testing lever. Each safety valve is fitted in a position independent of the steam outlet to the engine or of any other mounting.

The capacity of the injector should be at least 1½ times the maximum evaporative capacity of the boiler, and a spare injector or a feed pump should also be fitted to provide an alternative feed through a separate check valve.

Speeds.—The normal hoisting and travelling speeds for various sizes of standard portable jib cranes are about as tabulated below. The *slewing* speed is about 200 ft. per min. in all sizes, except that it may be increased to 300 ft. per min. for cranes of exceptionally long radii.

Capacity	Hoisting Speed	Travelling Speed
Tons	Ft. per min.	Ft. per min.
2	100	450
3	80	450
5	70	420
7½	50	400
10	40	350
15	30	300

Expressed in different units a speed of 450 ft. per min. is 5·1 miles per hour.

The British Standard Specification for Travelling Jib Cranes (No. 357 of 1930) recommends the following maximum speeds for self-propelled loaded cranes travelling on a straight and level track.

Combined Weight of Crane and Load	Maximum Speed
Tons	Ft. per min.
Up to 10	500
From 11 to 20	450
,, 21 ,, 30	400
,, 31 ,, 40	300
,, 41 ,, 50	250

CHAPTER VI

STABILITY OF LOCOMOTIVE CRANES

THE total *weight* of a contractor's-type steam jib crane varies a good deal with the gauge of the track. A wide gauge means economy of weight, from the point of view of stability. A convenient straight-line graph [1] may be drawn whose base is the product of the load into the radius, expressed in ton-feet, and whose ordinates represent the weight of the crane in tons.

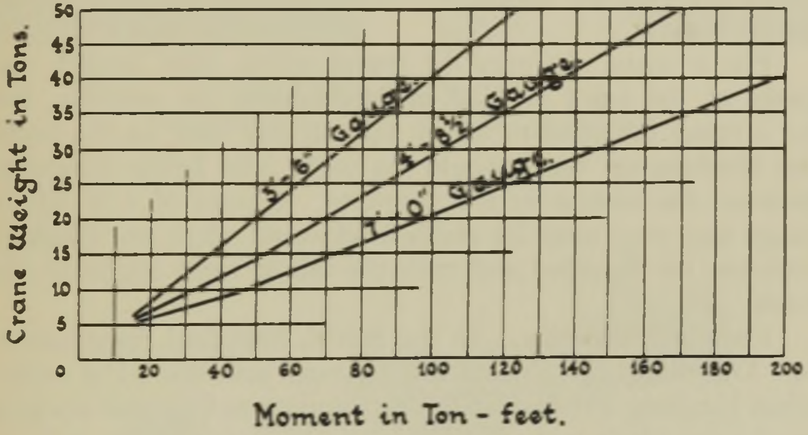

FIG. 48.—Graph of Jib-crane Weights.

A series of lines may be drawn, corresponding to various gauges below and above the usual standard track of 4 ft. 8½ in., as indicated in Fig. 48.

In the case of a 3-ton crane of 16 ft. radius the product representing the tipping moment is 48 ton-ft., and the graph line for 4 ft. 8½ in. gauge gives a total crane weight of about 15 tons.

At the same gauge and radius a 10-ton crane, having a tipping moment of 160 ton-ft., would weigh about 48 tons.

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[1] See "Cranes," by F. J. Wiggle, his page 10.

The graph shows that this weight would be reduced to about 33 tons when the gauge is increased to 7 ft., according to Wiggle's chart.

When long jibs are fitted an addition to the load must be made for the extra weight of the jib of, say, 0·2 ton for every 10 ft. increase in its length above 20 ft. Thus, for example, if a crane with a 50-ft. jib has to lift 3 tons at 40 ft. radius on a 4 ft. 8½ in. gauge, one should add to the load on the hook

$$(50-20)\div 10\times 0{\cdot}2 \text{ ton}=0{\cdot}6 \text{ ton}.$$

Then the corrected tipping moment becomes $(3+0{\cdot}6)$ ton × 40 ft. radius = 144 ton-ft. From the graph it will be seen that the total weight of such a crane would be about 43 tons.

In the case of a *grabbing* crane, where extra drag and overloading are probable, one should allow a 50 per cent. margin of stability on the combined weight of the grab and its contents.

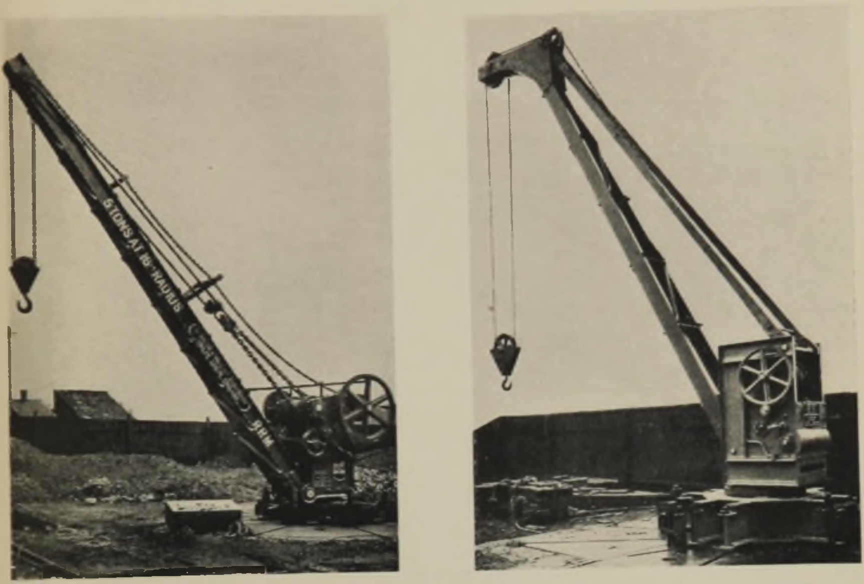
For a crane designed to travel when fully loaded, the gauge of the track is used in determining the stability, but for a crane intended to travel without any load on the hook, the blocking-up base should be used, this being measured between the centres of the supports. Cranes of 4 ft. 8½ in. gauge and over must be stable backwards when not blocked, with the jib removed and with the tail at right angles to the track.

Forward Stability.—In the British Standard Specification for Travelling Jib Cranes the forward stability of a crane, when handling any load at the appropriate radius, and working on a level track with the jib at right angles to the rails, is defined as " the *percentage* additional load required to bring the crane to the point of tipping." This must be not less than

$$\frac{\text{Radius of crane}}{\text{Gauge (or blocking-up base)}}\times F,$$

where F is a coefficient whose numerical value depends on the gauge (or the blocking-up base) and on the classification of the crane as to its position and service. For many jib cranes its value is roughly 10.

The chief factor in the calculation of stability is the ratio of the working radius to the gauge. The values of the



Joseph Booth & Bros., Rodley, Leeds.

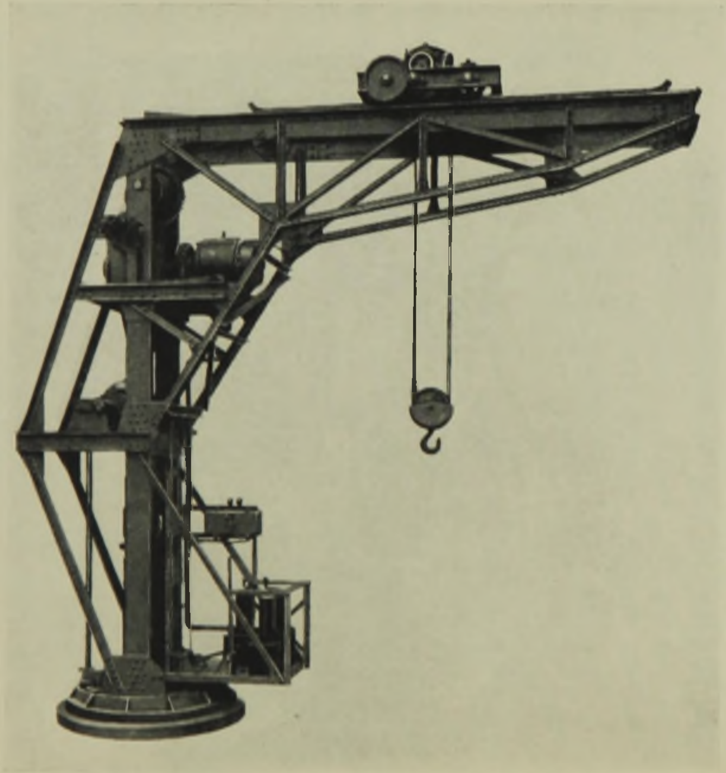
OLD AND NEW TYPES OF HAND JIB CRANES.

Ransomes & Rapier Ltd., Ipswich.

33-TON TITAN CRANE OF 1887.

[*To face page* 64.

PLATE 8



Craven Bros. Crane Division Ltd.

5-TON CANTILEVER FIXED CRANE.

Craven Bros. Crane Division Ltd.

25-TON FIXED COALING CRANE.

To face page 65.]

coefficient given in the table below are such as provide a suitable excess of righting moment over the maximum overturning moment, when the crane is at work on a level track and under the joint influence of the load and the wind pressure.

Class A cranes are those working on elevated structures, dock or quay walls, also those operating grabs. Class B cranes are those working on the ground on ordinary service, but not waterside cranes. The forward stability must be not less than 50 per cent. for class A cranes and not under 33⅓ per cent. for class B cranes.

Gauge (or Blocking-up Base)	Value of Coefficient F.	
	For A Cranes	For B Cranes
10 ft. or more .	11·1	7·6
9 ft. . . .	11·2	7·7
8 ft. . . .	11·5	7·9
7 ft. . . .	11·9	8·2
5 ft. 6 in. . .	12·8	8·9
4 ft. 8½ in. . .	13·4	9·4
3 ft. 6 in. . .	14·7	10·3
3 ft. 3⅜ in. (metre) .	15	10·5

Numerical Examples of Stability Calculations.—(1) When calculating the stability of a jib crane it is convenient to take moments about the hook or load line and to consider the superstructure quite independently of the truck in the first place. In the following typical example the weights and other figures are taken from Wiggle's pamphlet on "Cranes," in respect of a 5-ton crane of 20 ft. radius standing on a track of 5 ft. 6 in. gauge. The calculations have been checked and somewhat amplified. In the table on page 66 the *arm* is the distance from the hook at which the weight of each detail acts at its centre of gravity, while the *moment* is the product of the weight of the detail into its arm.

Thus the total weight of the crane superstructure alone is 249 cwt. or, say, 12½ tons.

Since the total weight acting at its centre of gravity must

Detail	Weight	Arm	Moment
	Cwt.	Ft.	Cwt.-ft.
Revolving bed	50	21	1050
Engines and shaft	20	22	440
Side frames	20	20	400
Barrel and wheel	10	19	190
Derrick gear	6	21	126
Tank	45	27	1210
Balance slabs	40	27·5	1100
Boiler, complete	35	27	945
Slewing gear	6	19	114
Control gear	3	21	63
Jib, complete	11	10	110
Tie-rods and ropes	3	10	30
	249		5778

have the same moment as the sum of the individual moments, we have

$$249x = 5778,$$

so that

$$x = 23{\cdot}2 \text{ ft.}$$

This is the distance of the centre of gravity of the unloaded superstructure from the load line or hook.

As the radius of the jib is 20 ft., the centre of gravity is situated 23·2 − 20 ft. or 3·2 ft. behind the centre pin.

Next, to find the centre of gravity of the *loaded* superstructure.

Since the total vertical load multiplied by the arm of its centre of gravity equals the sum of all the individual moments, we have

$$(249 + 100)x = 5778,$$

therefore

$$x = 5778 \div 349 = 16{\cdot}6 \text{ ft.}$$

Hence the centre of gravity of the loaded superstructure is 20 − 16·6 ft., or 3·4 ft. in front of the centre pin; and so the effective radius of the crane's roller path should be about this figure or, say, 6 ft. 9 in. diameter.

In order to find the centre of gravity of the entire crane (unloaded) one must take into account the weight and the moment of the under-carriage or truck as well as of the superstructure. Taking 13 tons as the weight of the truck, including wheels, axles, gear and slewing ring, and its centre of gravity as 20 ft. from the hook, we get the moments tabulated below :—

	Weight	Arm	Moment
	Cwt.	Ft.	Cwt.-ft.
Superstructure . .	249	23·2	5,778
Under-carriage . .	260	20	5,200
	509		10,978

Then $509x = 10{,}978$, or $x = 21\cdot56$ ft.

Thus the centre of gravity of the entire crane (unloaded) lies 1·56 ft. behind the centre pin.

As the half-gauge of the rails on which the crane is standing is 2·75 ft., its centre of gravity lies $2\cdot75 - 1\cdot56$ or 1·19 ft. inside the back rail, when the crane is slewed at right angles to the 5 ft. 6 in. track.

Lastly, when the crane is fully loaded with 5 tons on the hook, since the total vertical weight multiplied by the arm of its centre of gravity from the hook equals the total moments, we have

$$(509 + 100)x = 10{,}978,$$

therefore $x = 10{,}978 \div 609 = 18$ ft.

Hence the centre of gravity of the entire *loaded* crane is $20 - 18$ or 2 ft. in front of the centre pin. In relation to the 5 ft. 6 in. track, this point is $2\cdot75 - 2$ or 0·75 ft. inside the front rail.

Checking the stability of this crane by the B.S.I. rule given on page 64 we find that the forward stability in this case is

$$\frac{\text{Radius of crane}}{\text{Gauge of rails}} \times F = \frac{20}{5\cdot5} \times 8\cdot9 = 32\cdot4 \text{ per cent.}$$

As this figure is slightly below the 33⅓ per cent. specified as the minimum value of the forward stability, it is clear that a small amount of extra balance weight is required here, in order to ensure a sufficient margin of safety in the crane.

(2) In working out another numerical example of the stability calculations required for a portable jib crane, the figures and the method given by Joseph Horner will be adopted.

There are two distinct calculations needed, one to determine the stability of the crane with the load suspended, and the other to make sure that the crane is stable *backward* when the load is removed.

Assume the case of a crane (Fig. 49) to lift a load of 3 tons at a radius of 16 ft. on a gauge of 4 ft. 8½ in. The forward tipping moment is found by multiplying the weight of 3 tons by the distance it overhangs the rail, viz., 16 ft. minus half the gauge, say 2·4 ft., the product being 40·8 ton-ft.

The next step is to assess the margin of safety. This depends on the size of the crane and the nature of the work.

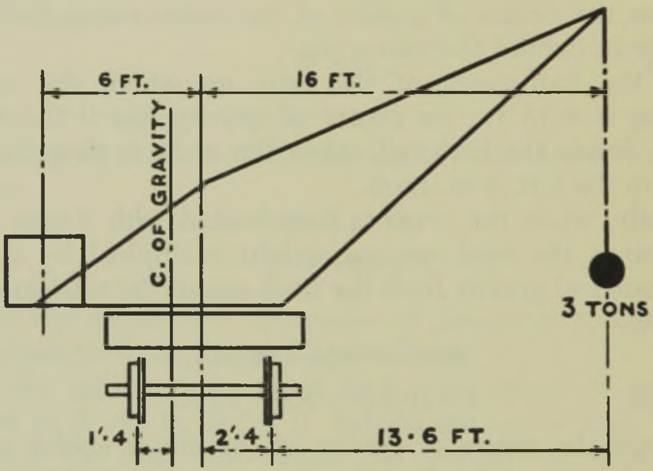


FIG. 49.—Diagram of Balance Crane.

For cranes up to 10-tons capacity, with radii up to 20 ft., a 20 per cent. margin is ample for ordinary work. In the case of cranes with long jibs and high gantry carriages, the allowance may rise to 50 per cent., whilst for high-speed cranes working in exposed positions, such as harbour portal cranes, a margin of 100 per cent. may be demanded in first-class specifications.

In the present case a 20 per cent. margin will be suitable as the amount to be added to the tipping moment, thus giving a total moment to be balanced of

$$40{\cdot}8+\frac{40{\cdot}8\times 20}{100}=48{\cdot}96 \text{ ton-ft.}$$

This is near enough to 49 ton-ft.

Now such a steam crane will weigh about 15 tons, and its centre of gravity will be about 1 ft. behind the centre line of the pivot, thus giving a total backward arm about the front rail of 1 ft. plus half the gauge, or 3·4 ft. Hence the backward moment of the whole crane is 15 tons × 3·4 ft. = 51 ton-ft.

As this figure slightly exceeds the forward moment of 49 ton-ft., the crane is quite stable both forward and backward, for the centre of gravity is 1·4 ft. inside the back rail.

(3) Next consider the case of a hand-operated portable jib crane. This would not exceed 8 tons in weight, and its centre of gravity would be practically on the centre line, giving a total *backward* moment of 8 tons × 2·4 ft. = 19·2 ton-ft. Subtracting this figure from the *forward* moment of 49 ton-ft. we get 29·8 ton-ft. as the unbalanced moment. Thus the crane is not stable, but this deficiency can be made up by adding ballast to the tail of the crane.

With a tail radius of 8 ft. and a centre of ballast weight of, say, 6 ft. from the crane centre, the total effective distance from the front rail is found to be 8·4 ft. Dividing this figure into the unbalanced moment we get 29·8 ÷ 8·4 = 3·54 tons of ballast needed to maintain stability.

A final calculation is required to find out whether this hand jib crane is going to be stable *backward* when the load is removed from the hook. The backward moment is the weight of the ballast multiplied by the distance it overhangs the rear rail, *i.e.*, 3·54 tons × 3·6 ft. = 12·7 ton-ft. Adding a 20 per cent. margin we get 15·2 ton-ft. to be balanced by the crane. As the moment of the crane itself inside the rail is 8 tons × 2·4 ft. = 19·2 ton-ft., and this exceeds the backward moment of the ballast, the crane is clearly stable backward.

In the case of this hand portable crane, if we had attempted to do the same duty on a narrow gauge of 3 ft. 6 in., we should have found that so much ballast would be needed as to render the crane unstable backward when the load was taken off the hook, unless we added weight to the crane itself.

In such cases, however, it is usual to provide blocking girders and to mount the ballast on wheels, the aim being to move the weight nearer to the crane centre when not in use and so reduce its overhang to a safe limit when the blocking girders are not in use.

Rail Clips and Blocking Beams.—These accessories are useful for improving the stability of most portable cranes. The usual form of rail clips is shown in Fig. 50. Each pair of clips is hung from a plate B bolted to the truck by the long eye-bolt C. When not in service the clips are raised clear of the rails. When needed they are secured in place by dropping the loose clip D over them. The rail clips then bind the truck fast to the rails and so prevent it from upsetting under unfavourable conditions.

In their simplest form blocking beams or girders are rolled steel *joists* of sufficient length to ensure the stability of the crane when heavily loaded and slewed across the track.

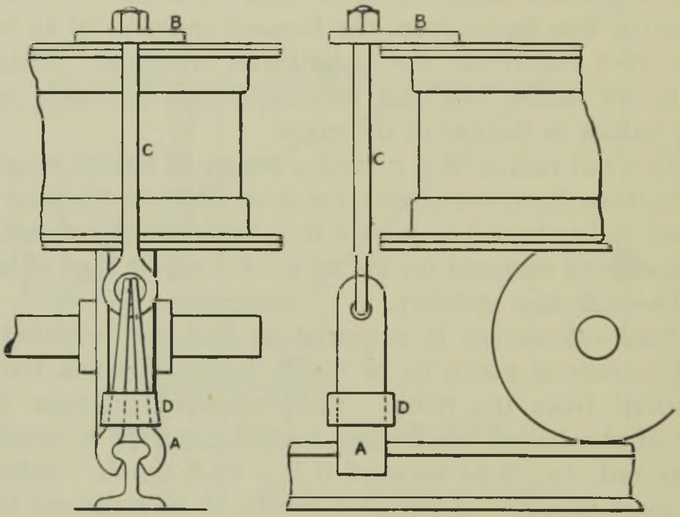


FIG. 50.—Rail Clips.

Any crane is capable of lifting its rated load at maximum radius when the jib is in a longitudinal position, *i.e.*, in line with the wheel-base of the truck. But relatively few cranes, save those of very short radius or of specially wide gauge, will lift their rated load at full radius when slewed across the track.

Between these two extremes there is a certain angle at which the stability of the crane becomes insecure, when artificial aids to stability are needed. Formerly these aids were liable to be abused, and it became necessary to develop improved designs of cranes ordinarily capable of lifting the full load in any position without the aid of either blocking girders or of rail clips, except in the case of long-radius cranes.

Blocking beams, when fitted, are supported loosely in straps, as seen in Fig. 37. If made in one piece the joist always projects on each side of the truck. When this is objectionable the blocking joist is made in two pieces, capable of sliding in and out, or alternatively *hinged*, so as to be flush with the truck sides when out of action.

Instead of joists, broad blocks operated by vertical screws in sliding bearings standing out from the sides of the truck are sometimes fitted, the blocks being lowered down to rest on the ground when required.

Timber packings are laid beneath the ends of the blocking beams when put into service. Occasionally one fits rail clips as well as beams, thus enabling that method to be used which happens to be the more convenient at the time.

BREAKDOWN CRANES

This type of locomotive jib crane is also known as an 'accident' or a 'permanent way' crane. In America such cranes are made up to 100 tons lifting capacity and styled *wrecking* cranes. Though used in general railway service the special duty of a breakdown crane is the disentanglement and removal of the debris resulting from serious railway accidents and restoring the tracks generally. The jib is made of the swan-neck form to give a maximum of head-room.

One essential difference between this and the ordinary portable crane is that the truck must fulfil permanent-way requirements by having the standard wheels, axle boxes, horn blocks, leaf springs, buffers, drawbars and other details all made to suit the particular railway in question. A breakdown crane must have an ample margin both of power and of strength, for it must be absolutely reliable under the most severe conditions of working.

On cranes of over 15 tons capacity, live-roller slewing rings are fitted instead of the four-roller design usual on smaller cranes. The side-frames and the truck are steel plated, as being better fitted to withstand shocks than is cast iron. Many cranes have six running wheels instead of four, while some have eight wheels. In the latter case four of the wheels form a bogie and the other two axles are driven by spur gearing from a vertical shaft passing down the centre post. The intermediate wheel between the two axles is arranged to disengage by means of a hand wheel and screw when the crane is coupled up to a train. Tail-locking gear is also fitted, to prevent the tail of the crane slewing round when running.

In addition to the usual blocking girders or joists sometimes a pair of jointed legs are provided, to serve as a strut or prop to the jib head when the crane is being used to *pull* loads that might overcome its stability. Though the jib is comparatively short in all ' wrecking ' cranes, the hoisting rope may occasionally be payed out well beyond the end of the jib and used to drag an object within the lifting orbit.

Although these cranes are usually steam-driven, some American wrecking cranes used in tunnels and subways have been equipped for electric operation. Current is taken either from a third rail or through a flexible cable and a plug-in connection, or through an overhead trolley, or even from storage batteries carried on the crane.

Modern Examples of Breakdown Cranes.—Several good examples by prominent makers are illustrated in the photographic views on Plates 11 and 12. These are worthy of careful study and comparison. It will be noticed that some designers of steam cranes favour horizontal engines while others prefer inclined engines.

Although the vast majority of breakdown cranes are steam-driven, yet hand-operated cranes are not entirely unknown. The combined hoist and derrick gears of a *hand* breakdown crane are so arranged that as the derrick rope is wound in the hoist rope pays off in the correct ratio to give an almost level path for the travel of the load. This enables the full load to be derricked with comparative ease and greater safety.

The ' Booth ' 20-ton *steam* crane of 3 ft. 6 in. gauge, with its jib carried by a long ' match-truck ' when in transit, is specially adapted for bridge erecting. This crane has six axles, and the match-truck is fitted with two four-wheel bogies. There are two sets of blocking joists, snugly housed or rectracted, as depicted on Plate 11.

In some cranes the blocking joists are replaced by hinged brackets or ' outriggers ' which fold neatly against the truck sides when housed. When in use they are swung outward and supported on blocks or by screw jacks. These outriggers effectively supplement the ballast or counterbalance weights and greatly increase the stability of the crane.

The six extended outriggers are well shown by the photographic plan view (Plate 12) of a ' Craven ' steam crane minus its jib and the usual relieving bogies for distributing the wheel loading when in transit. This instructive view also shows the various rope drums, gears and operating clutches embraced in the machinery.

The ' Cowans ' 120-ton steam crane (Plate 12) made in 1925 for the South Australian Railway has four sets of telescopic blocking joists. With all these extended the full load is lifted at 17 ft. radius (the moment being 2040 ton-ft.), or 30 tons at 37 ft. radius. With the end joists only in use these loads are reduced to 45 and 12 tons respectively. With the crane quite free on its rails the load becomes 15 tons at 17 ft. and only 4 tons at 37 ft. radius.

A few more technical details of this fine crane will be of interest. The rail gauge is 5 ft. 3 in., the wheel-base 19 ft. 9 in. and the bogie centres 13 ft. 9 in. The height of lift of the main block at 17 ft. radius is 24 ft. above the rail level and of the auxiliary block at 23 ft. radius it is 31 ft.

The horizontal engine cylinders are 10 in. diameter by 12 in. stroke. The hoisting speeds are 120 tons at 10 ft. a min. and 30 tons at 40 ft. a min. The slewing speed is one revolution in 1½ min. The derricking time is 1½ min. for the full range. Lastly, the travelling speed is 4 miles per hour when the crane is carrying a 15-ton load.

Plate 11 depicts a ' Rapier ' steam crane equipped with Stokes' relieving bogies, together with a short match-truck, all in train order. This crane has four axles and four sets of blocking joists. On such a crane the weight is distributed over a long flexible wheel-base, when travelling in train, by coupling at each end either a four-wheel or a six-wheel bogie. Moreover a short *fixed* wheel-base is secured after removing the bogies when the crane is lifting very bulky loads.

The match-truck being short can be placed by the crane on its own tail either fore or aft, so that it is possible to move the crane right up to the work before the match-truck and the bogies are removed, which is a great advantage in this design.

A Noteworthy Model Crane.—In concluding this account of locomotive cranes one may fitly refer to a wonderful model of a ‘ Craven ’ railway service crane which is exhibited in a glass case at the Euston Station, London, of the London Midland & Scottish Railway Company.

This model of a 36-ton crane, one-tenth of full size, was made by an enthusiastic amateur engineer, Mr S. J. Ward, of Northampton, to detailed particulars furnished by Craven Brothers Crane Division Ltd., of Loughborough. It is an actual working model, fitted with relieving bogies and complete in every detail. The model is a truly superb piece of mechanical work, done by one man as a labour of love.

The actual crane is capable of lifting 36 tons at 24 ft. radius or 18 tons at 40 ft. radius, after the axle-spring packings have been inserted, the rail clips fitted and the draw-out beams blocked up. When free on its rails, however, the crane will lift only 3½ tons at a radius of 40 ft.

CHAPTER VII

DRUMS AND PULLEYS

Types of Drums.—The hoisting drums or barrels of cranes are made in many diverse forms, ranging in diameter from 6 in. to 8 or 9 ft. They are either plain cylinders, double flanged, as in Fig. 51, or are grooved spirally, the grooves being made to take either chain, as in Fig. 52, or wire rope, as in Fig. 53. The spiral grooves may run in one direction only or they may be right and left handed, so as to lift the load always centrally. Drums are usually cast, bored and

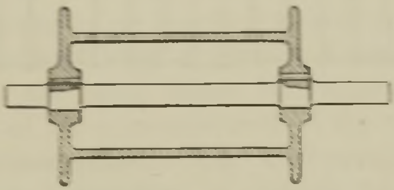


FIG. 51.—Flanged Drum for Chain.

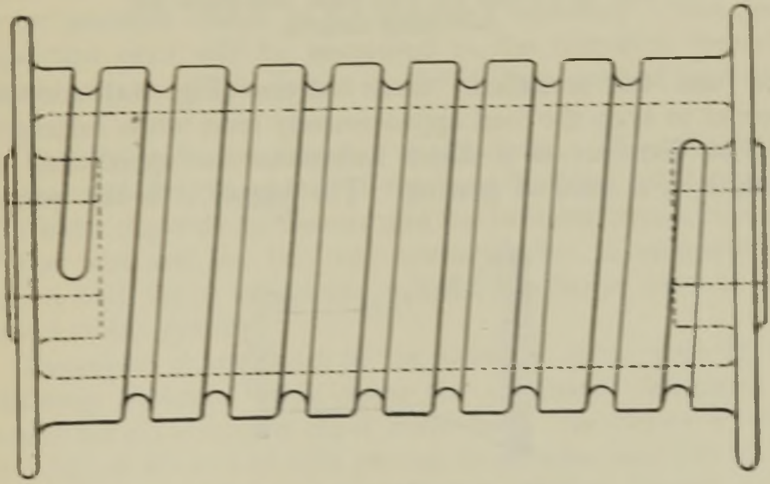


FIG. 52.—Grooved Drum for Chain.

keyed on their shafts, but in a few cases the drum-ends only have been cast and the body made of steel plates. In some derrick cranes the parallel form of drum has been departed from and the so-called 'fusee' drum (Fig. 54) adopted, in order to keep the load approximately level when luffing.

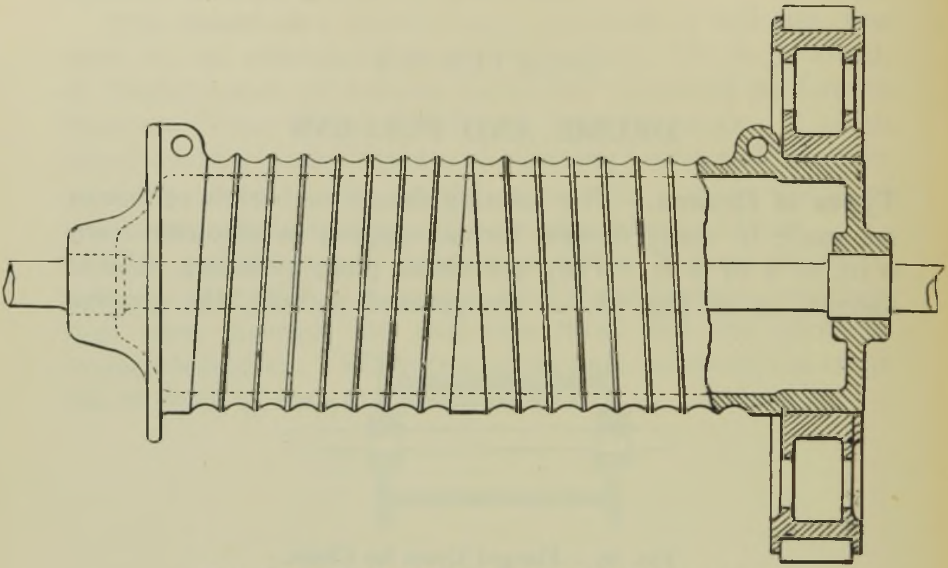


Fig. 53.—Drum for Wire Rope, with Right and Left Hand Grooves.

The diameter of a drum influences the speed and the strength of a train of gearing. The bigger it is the quicker the rate of hoisting, the gearing ratio remaining the same. Hence the drums of quick-hoisting cranes are often of larger diameter than those for much more powerful cranes. To take the torsion off the shaft the main driving wheels are

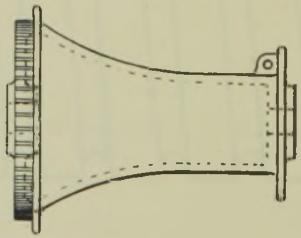


Fig. 54.—'Fusee' Drum for Derrick.

often secured directly to drums by fitting them over the body or against flanged ends. The largest drums may have two wheels keyed on, one at each end.

When making plain drums up to about 24 in. diameter in the foundry, entire patterns are used, but above that size loam moulds are struck. Even for cranes of standard type the sizes of drums are often varied to suit different lifts, while in miscellaneous work drums occur of all diameters and lengths.

The objection to *plain* drums is that there is no guidance to cause the chain to lie in even laps, and so there is some risk of overriding. Hence grooving is adopted in all save the smaller hand and power cranes. There are two kinds of grooves, one where the chain links lie diagonally and the other where they lie flat and edgewise alternately. In the latter case there is practically no bending action on short link crane chain if the drum is of large diameter. Drums for wire ropes have grooves of the same shape but narrower, to embrace about one-third of the circumference of the rope.

B.S.I. Requirements.—The recommendations of the British Standards Institution as regards hoisting drums are much the same whether the drums are designed for derricks or for portable cranes or for overhead travellers. The more important ones will be embodied in the following remarks, which refer to crane drums made of close-grained grey cast iron :—

1. As regards the *diameter* of the drum. This dimension is governed by the speed of the rope and by its flexibility. The latter depends on the size and the ultimate tensile strength of the wire and on the rope construction. Commonly the rope is built up of six strands, but the number of wires in each strand varies greatly.

Expressed in multiples of the diameter of the rope D, the following abridged table gives the minimum diameters of drums for six-stranded ropes made from two classes of wire, viz., (A) of 80 to 110 tons per sq. in. tensile, and (B) of 110 to 130 tons tensile, the latter wire needing bigger drums for a given diameter of rope because less flexible. For example, if a 1-in. rope has 24 wires per strand and is made of class A steel, then the drum should be at least 19 in. diameter, whereas if made of the stiffer class B steel, it should be at least 22 in. diameter.

Wires per Strand	Diameter of Drum (Min.)	
	For Steel A	For Steel B
19	23D	27D
24	19D	22D
37	16·5D	19D
61	13D	15D

The normal rope *speed* is anything up to 120 ft. per min. If the rope is run faster than this, the diameter of the drum should be increased by one thickness of the rope for every rise in speed of 30 ft. per minute.

2. As regards the *contour* or shape of the grooves, this should be circular over an angle of 120°, and smoothly turned to a radius slightly larger than the radius of the rope by an amount varying from $\frac{1}{32}$ to $\frac{3}{32}$ in., as the ropes increase in *girth* from 2 to $2\frac{3}{4}$ in.

The *pitch* of the spiral grooves should be such as to allow a clearance of at least $\frac{1}{16}$ in. between the adjacent turns of rope.

Although formerly grooved drums were sometimes cast from patterns, it is better and cheaper to cut the grooves in a suitable screw-cutting lathe.

3. The length or *width* of a drum is governed by the height of lift and the number of falls of rope. It should be sufficient to accommodate in one layer two dead turns over and above the length of rope requisite for the specified lift, when no more than 10 ft. of hoisting rope requires to be wound on and off the drum. As the rope winds up, its inclination to a plane perpendicular to the axis of the drum should not exceed 1 in 12.

If a rope is wound on a drum in more than one layer, then its anchorage must be fixed clear of the winding, preferably outside of the flanges, but the use of overlapping ropes is discouraged. All rope anchorages should be readily accessible.

4. As regards *flanges*, all drums when not grooved have to be flanged at *both* ends. This applies also to *grooved* drums on which a rope is coiled in more than two layers ; but *one* flange suffices when a grooved drum has less than two complete

layers of rope. Note that a spur-wheel spigoted to a drum is here equivalent to a flange.

Anchorages.—Secure attachment of chains and ropes to hoisting drums or barrels is essential for safety, various methods of securing their ends being employed, as shown in the illustrations.

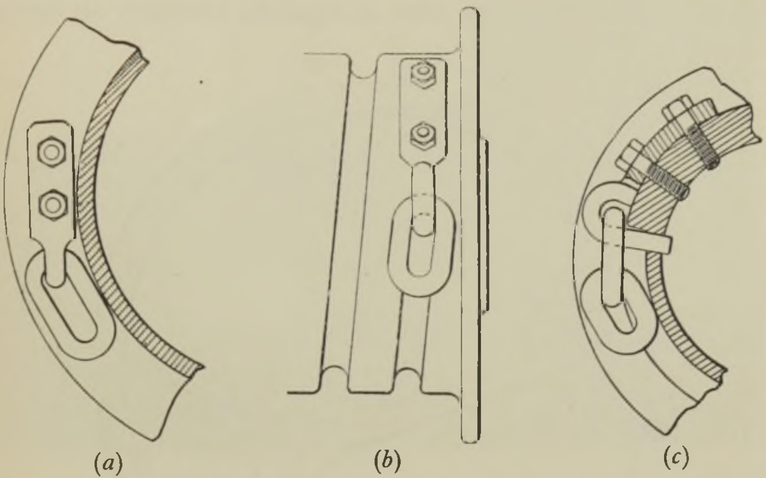


Fig. 55.—Chain Anchorages.

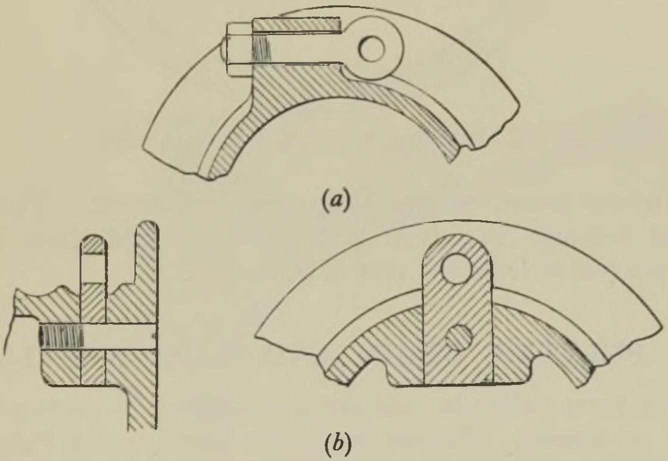


Fig. 56.—More Anchorages.

One way is to bolt an anchor hook to a flange (Fig. 55, *a*) or to the body of the drum, as shown in elevation and cross section by *b* and *c*. Another and better way is to cast a lug on the drum (Fig. 56, *a*) and to pass an eye bolt through it.

A further good method (Fig. 56, *b*) is to bore a hole in the drum to receive the end of an eye link and then fasten this link by a screw passed through from the end of the drum.

In the case of a wire rope the best method is that shown in Fig. 57. Here the wire rope is brought through an opening cast in the drum, its eye embracing a thimble. The eye is passed between two lugs cast internally and there secured by a pin put in from the end of the drum.

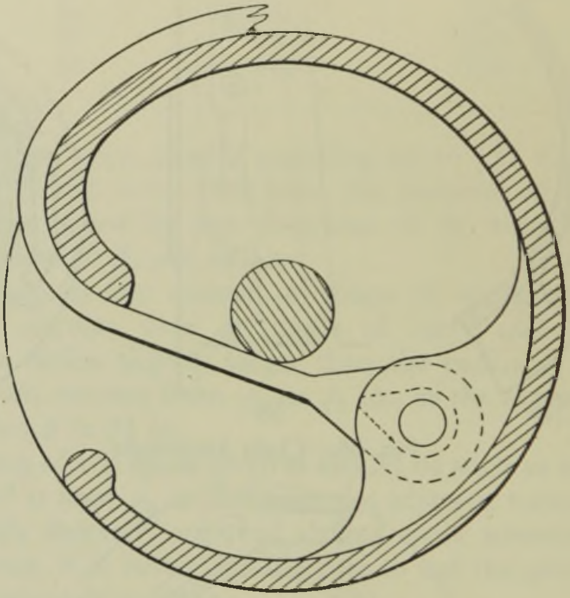


Fig. 57.—Best Anchorage for Wire Rope.

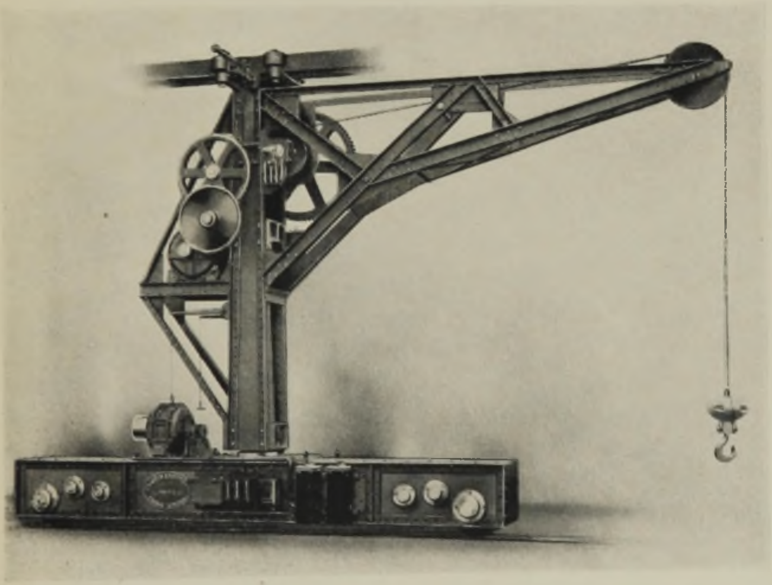
PULLEYS, CHAIN AND ROPE WHEELS

The term pulley is used comprehensively to embrace many kinds of wheels. Pulleys on cranes are applied for various purposes but chiefly (1) for *driving*, or transmitting power, (2) for *guiding*, or altering the direction of motion of chains and ropes, and (3) for *supporting* the load, as in hoist blocks. Grooved pulleys are preferably styled *sheaves* when serving in the second and third capacities stated.

Pulleys are made either plain or cupped to receive the links of chains. Also, they can rotate simply by the coercion of their chains or ropes, as when hoisting, or on the other

Ransomes & Rapier Ltd.

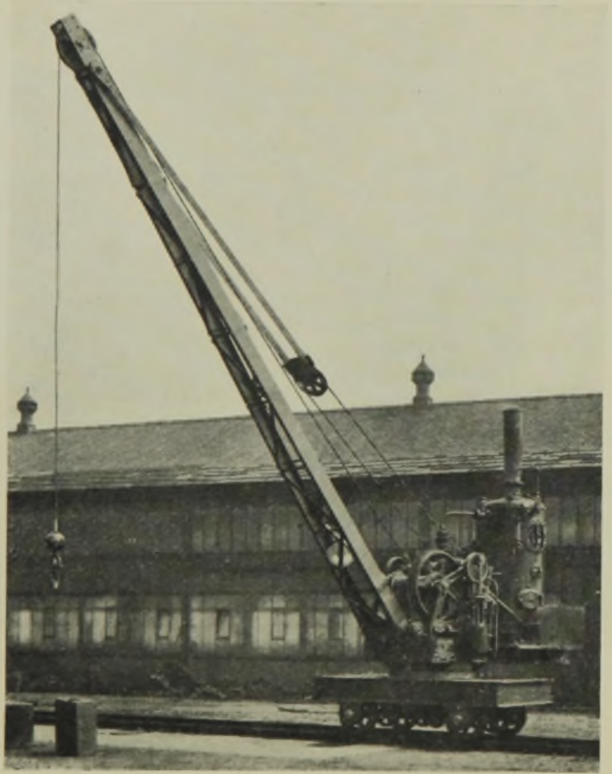
8-TON ELECTRIC LOCOMOTIVE CRANE.



Craven Bros. Crane Division Ltd.

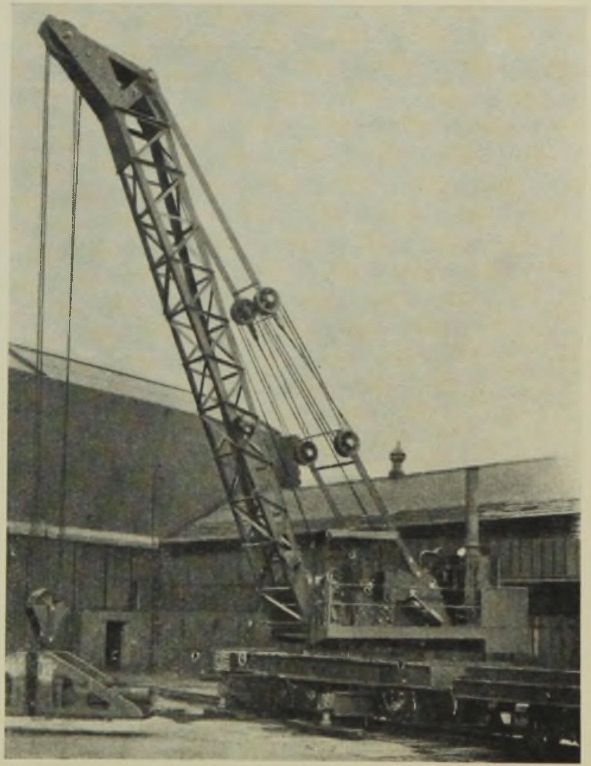
5-TON ELECTRIC WALKING CRANE.

PLATE 10



Joseph Booth & Bros.

3-TON CONTRACTOR'S LOCOMOTIVE CRANE.



Joseph Booth & Bros.

20-TON CRANE FOR BRIDGE ERECTING.

To face page 81.]

hand they may exert a pull on the chain, as in cupped drums and sprocket-wheels, which are used for the travelling and other gears of cranes.

As illustrated in Fig. 58, the shapes of pulleys vary with these functions and with the sort of lifting agent employed, viz., either short-link chain or round wire rope or hemp rope. Plain grooved wheels for chains are those whose rim section is uniform all round.

A concave section as at A is very common, but it is slightly open to objection, because the chain lies diagonally in the groove and is subject to stress due to the side pressure of the links. But the chief practical evil is that the chain is liable to twist in its length, since no coercion is exercised to keep it in line. Moreover the flanges of this sheave are apt to get broken by the surging of the chain or by the accidental running up of the hook. Hence this section of sheave is more suitable for use with a guide chain than with hoisting tackle.

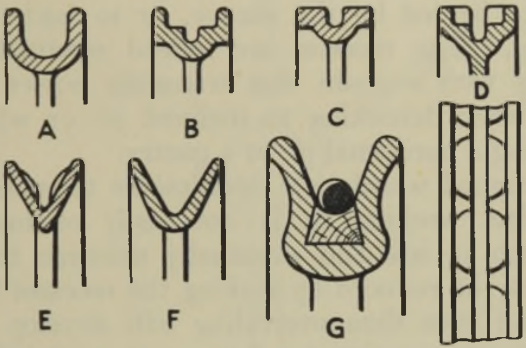


Fig. 58.—Sections of Chain and Rope Wheels.

The common type B in Fig. 58 has the advantage of preventing a chain from twisting, as the links lie flatwise and edgewise alternately. The only drawback is the risks of the flanges getting broken by the surging of the chain and hook. The flanges will also fracture if the chain links are made a tight fit laterally. On no account must the flanges be allowed to come in contact with the chain links ; in fact a side *clearance* of from $\frac{1}{8}$ to $\frac{1}{4}$ in. must be given. Without this clearance the chain will bear hard against the flanges and is apt to burst parts of them off.

For a rapidly moving chain liable to surging, *flanged* sheaves are a safeguard and should always be provided. All chain pulleys of this class must be of large diameter, otherwise the links are unduly stressed by the bending action. But in slow-moving cranes like some of the hydraulic type, flanges are often omitted, as in type C, since there is no real need for them in such cases.

The diameter of a plain sheave should be at least 30 times the diameter of the bar of iron or steel from which the chain links are made. But if the sheave is recessed to receive each link, instead of being made plain, a great reduction in size may be effected, because each link then has a flat bedding and all bending action is eliminated.

This cupped form of pulley D (Fig. 58) is used when the chain has to be led by the sheave, or to lead it positively without slip. The recesses are indeed essential when the pulley gears with a chain that transmits power as well as motion, as when derricking an inclined jib or when racking a trolley along a horizontal jib or a gantry.

These cupped wheels are troublesome to make correctly, and a perfect working fit is not easily retained, because chains stretch in use and eventually override the recesses. This evil may be reduced by making the recesses longer than the links, but even then overriding will develop in pulleys of large diameter receiving a fair number of links. Hence these wheels are usually made of small diameter, when no such trouble need occur.

There is another form of sheave or wheel used for small chains and for ropes, the groove being of V section E, with nibs cast at intervals to aid the bite of the chain pulling the wheel round. Wheels of this kind are used for actuating the trolleys of wall and foundry cranes, as well as on overhead hand travellers worked from below by pendent chains or ropes. They are made either wholly of cast iron or with wrought iron or steel arms cast into the rim and into the boss. Pulleys for ropes F and G do not need nibs cast on, as the friction of a rope will hold in a smooth V groove, whereas a chain would slip without nibs. The bite of a rope is also increased by the use of guide-pulleys, which increase the arc of contact of the rope.

Sprocket-wheels are a special type of chain-wheel used with pitch chain, for transmitting motion and force to the travelling wheels of portable and of Goliath cranes. Sprockets are designed with the idea that, when a wheel and chain are in engagement, several teeth are acting and no slipping can occur. But though a wheel and chain may be made to fit thus when new, yet as soon as put to work the chain begins to lengthen, so that after some service it can never be in effective contact with more than one tooth at a time.

Rope-wheels have come into extensive use since the development of the wire-rope industry. Before that, rope wheels were made only for cotton and hemp ropes—forms which have much in common. Pulley grooves should always be smoothly turned, to prevent the fraying out of the wires or of the fibres of which the rope is composed, for a rough-cast rim would wear out a rope very quickly In a correct section for a rope-wheel the rope bears only on the bottom of the groove. The side clearance prevents the injurious friction that would occur if the rope were in contact with the groove round its semi-circumference.

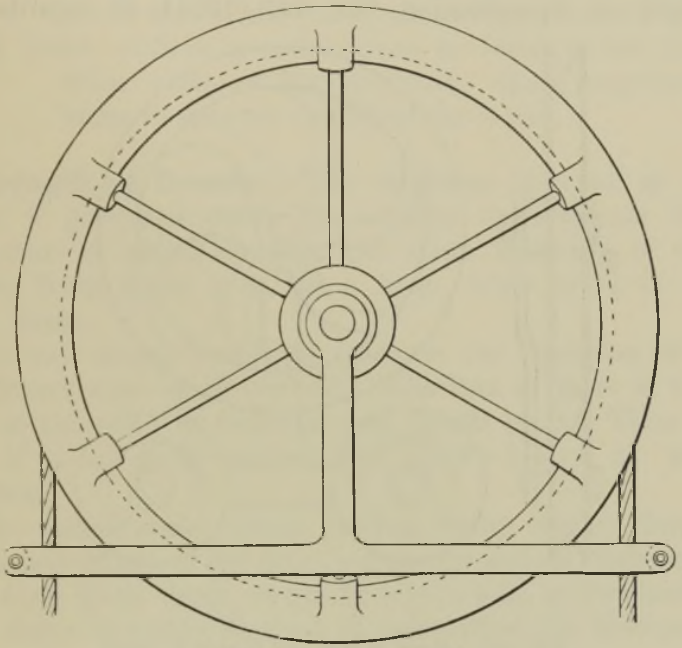


Fig. 59.—Rope-wheel.

Fig. 59 illustrates a form of rope-wheel with wrought-iron or steel arms, which are ‘ strutted ’ where they enter the boss into which the ends are cast. Fig. 60 shows another design with cast-iron rim and arms, also the guide sheaves that are often added to increase the arc of contact. Both these styles of rope wheels have been used largely on overhead hand travelling cranes operated by pendent ropes. In each case T-shaped rope guides are fitted round the centre-pin to prevent a slack rope slipping off the pulleys.

The requirements of the British Standards Institution set forth in Specification No. 327 (1934), as regards rope pulleys, are more or less embodied in the foregoing remarks, but they may be here recapitulated as follows :—

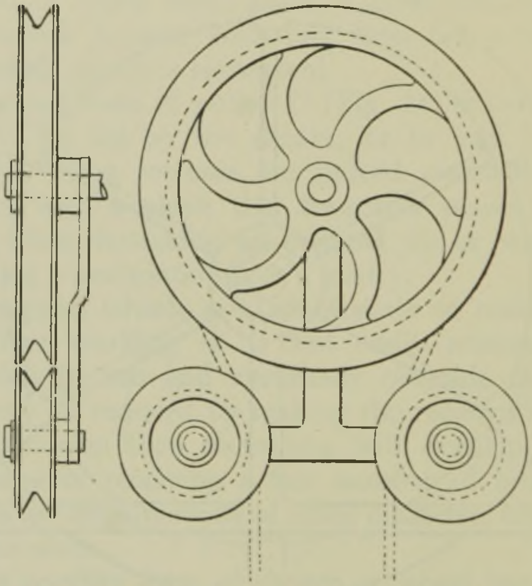


Fig. 60.—Rope Wheel and Guide Sheaves.

(*a*) The diameter of the lifting rope and of the derricking rope pulleys at the bottom of the groove must be not less than the diameter of the hoisting drum as specified on page 77.

(*b*) Rope pulleys are to be machine-grooved to a depth of at least 1½ times the diameter of the rope, the contour at the bottom of the groove to be circular over an angle of 120°. The radius of the circular part of the groove must be larger than the radius of the rope by at least $\frac{1}{16}$ in. for ropes of 3 to $3\frac{1}{2}$ in. girth. The grooving is to be smoothly finished and free from surface defects liable to injure the rope.

(*c*) Where pulleys are difficult of access they are to be of a self-oiling type.

(*d*) Pulleys carrying ropes that are periodically unloaded are to be provided with guards to retain the ropes in the grooves.

(*e*) The angle between the rope and a plane perpendicular to the axis of the pulley should not exceed 1 in 12.

(*f*) Guide pulleys or rollers must be fitted to the jib and other parts of the structure, where required, in order to prevent chafing of the ropes.

Strength of Drums.—The thickness of metal in crane drums is governed partly by foundry requirements in the production of sound castings, the actual thickness of drums ranging from about $\frac{5}{8}$ in. for a 10-in. drum to $1\frac{1}{2}$ in. for a 30-in. drum.

Yet two simple empirical rules for the thickness of cast-iron drums may be of interest. The first of these is to add 1 in. to the girth of the rope and divide by 5. Thus for a rope of 3-in. girth we get $(1+3)\div 5=\frac{4}{5}=0{\cdot}8$ in. as the thickness.

The second rule, which gives a rather thicker drum, is to take one-fiftieth of the drum's diameter and add half an inch. Thus for a 20-in. drum we get $\frac{20}{50}+\frac{1}{2}=0{\cdot}9$ in. as the thickness.

A more scientific method of calculating the thickness of a drum would be to treat the drum as a hollow beam subjected to both a maximum shearing force and a bending moment, and also capable of resisting the maximum torque due to the gearing. Though this rather lengthy process is not necessary in all cases, it is a wise check in specially important and unusual jobs.

Jib-head Pulleys.—A simple jib-head fitting carrying a chain-wheel or sheave is shown in Fig. 61. Two pieces of steel plate A are bolted between the joists or the channels forming the jib and are cranked to receive a distance-piece B, which also serves to prevent the chain from jumping outside of the wheel.

Two castings C′ are fitted outside the joists of the jib and are secured to them by bolts passing through A and C′, which details are bored in position to receive the head-pin D. These castings have extended bosses over which tie-rod eyes fit and are retained in position by the washers E.

In other designs instead of fitting separate plates A as shown, the jib sides are extended somewhat, their flanges are cut away and the web is set over to receive the distance-piece. Alternatively, castings may be fitted instead of steel plates.

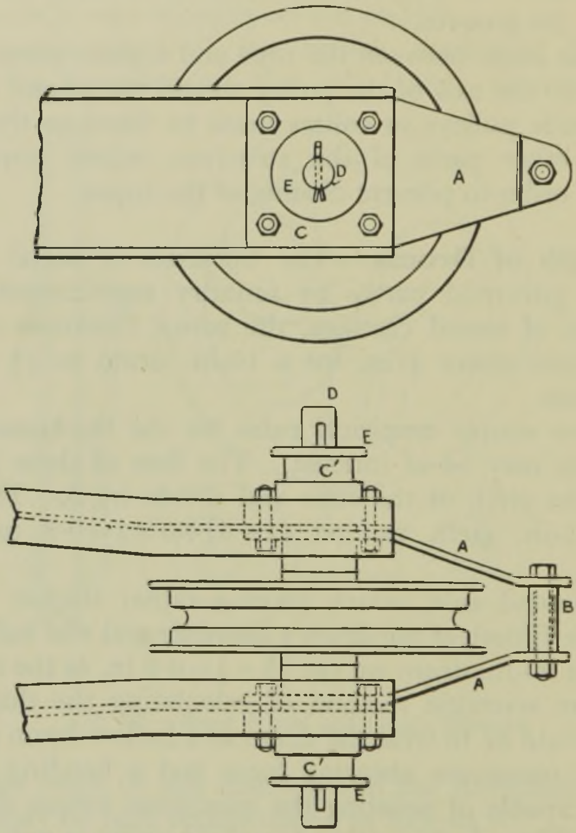


FIG. 61.—Jib-head Fitting for Chain-wheel.

In modern cranes the jib-head pulleys are now made much larger in diameter for wire ropes than they were ever made for chains, in order to increase the life of the ropes, small pulleys being very detrimental.

Supporting Rollers.—When the lifting chain or rope leads on to a head pulley in a horizontal line, the jib needs no supporting rollers. But if the chain comes up in a line parallel,

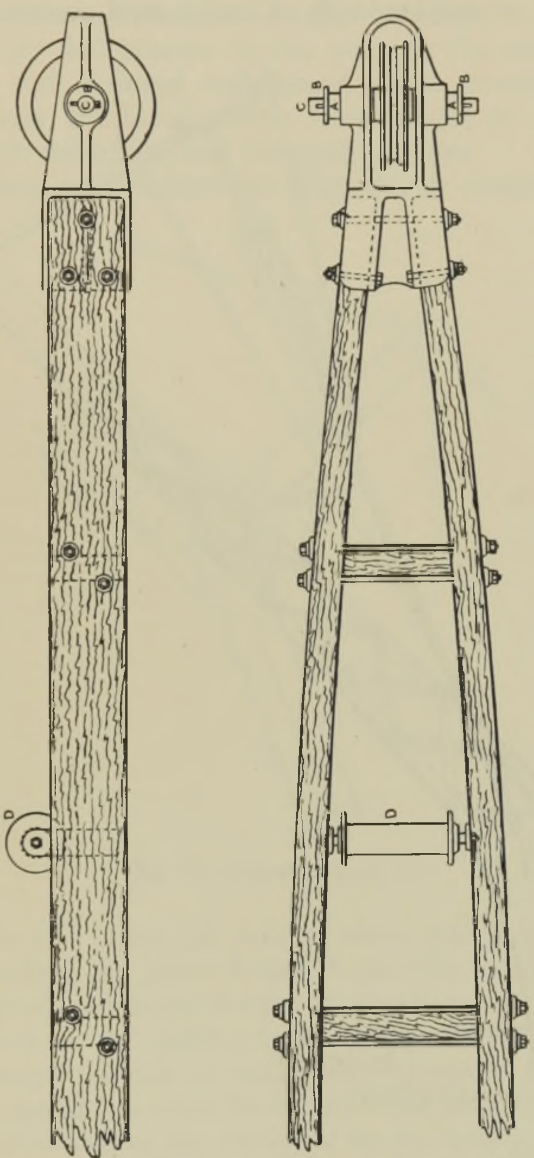


FIG. 62.—Jib-head Casting and Rollers.

or nearly so, with the jib, then its sag is taken on loose rollers carried from bearings fixed to the jib, whether this be constructed of wood or of steel. These rollers are seen at D in

Fig. 62, which also shows the jib-head casting carrying the head sheave from the side timbers.

A bent or cambered jib of lattice-steel construction, fitted

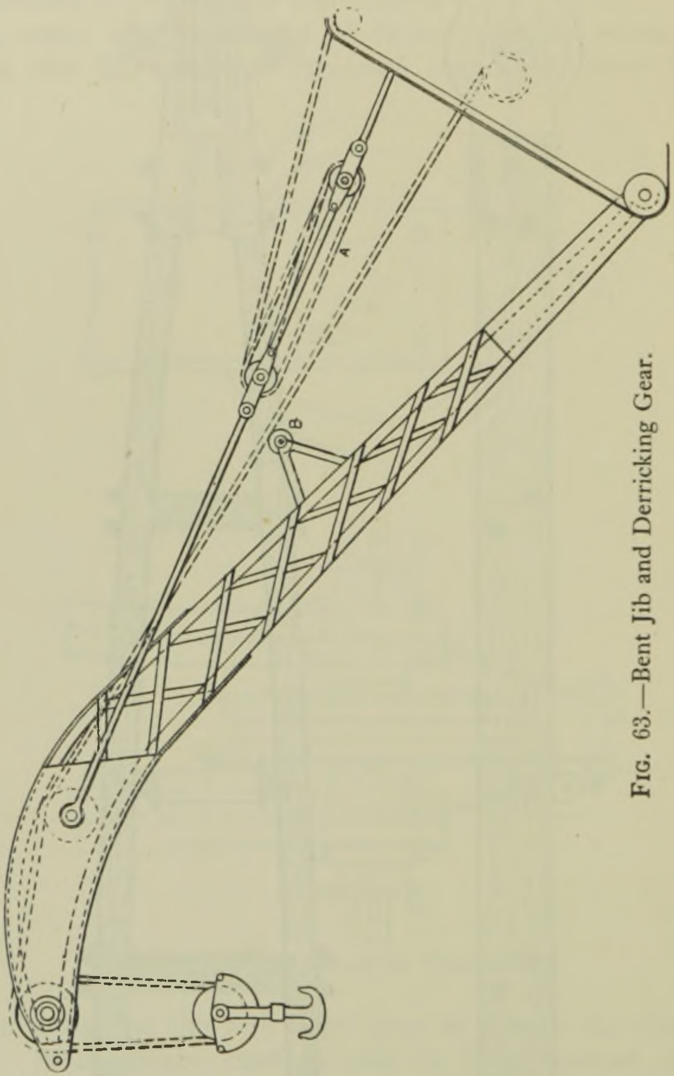


FIG. 63.—Bent Jib and Derricking Gear.

with derricking gear, is shown in Fig. 63, where a chain supporting roller is seen at B. In this design two rigid tie-rods are attached at one end with eyes to the jib-head castings, while at the other end the rods are furnished with looped forgings to embrace sheaves and receive their pins. These sheaves guide the derricking chains A that come from the derrick barrel within the crane frames. In this illustration the lifting chain and its drum are also indicated.

At the top and bottom of this bent jib the corner angles are united and stiffened with broad plates riveted to them, while castings are fitted within these plates to receive the pins for both the lifting and the guide pulleys.

A cranked and strutted jib (Fig. 64) is cheaper to make than a bent jib. Here the joint is made with a broad gusset plate E covering the joints A and B, also the castings F fitting in the channels, all being riveted up together.

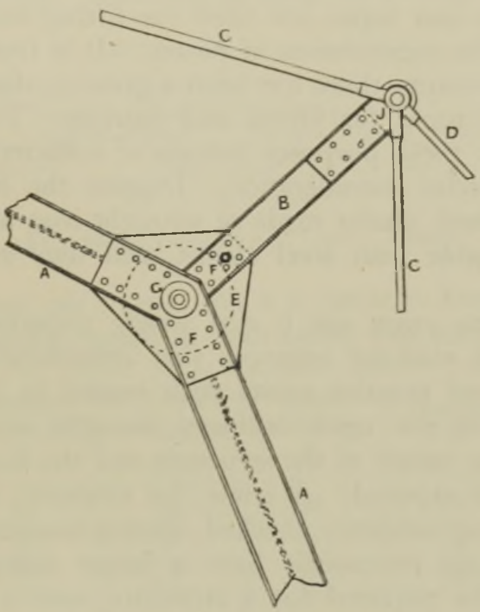


Fig. 64.—Cranked Steel Jib.

A boss G on the casting forms the bearing for the pin of a guide sheave (shown dotted) which conducts the chain or rope from the lifting drum to the jib-head sheave.

This guide sheave fits freely on its pin and slides along it from one side to the other, as the chain winds from end to end of its drum. A casting J or a forging is fitted into the head of the strut B to take a pin, over which the tension rods C and D are looped.

CHAPTER VIII

CHAINS AND ROPES

Both chains and ropes are used for lifting and hauling as well as for the transmission of power. It is true that during the present century there has been a growing disuse of chains in favour of ropes for lifting and hauling. Yet the chains still used for these purposes remain of sufficient importance to justify careful consideration. Despite the higher tensile strength of steel, chains made of wrought iron are thought to be more reliable than steel chains, and they are less liable to corrosion.

Some sixty years ago it was wisely remarked in an old book [1] by an eminent engineer that considerable difference of opinion and practice exists with regard to the safe load which may be put upon ordinary wrought iron, depending greatly on the nature of the structure and the kind of stresses to which it is exposed. A crane, for example, with the risk of a load being suddenly checked, during lowering, by a rash attendant, must necessarily have a larger margin of safety than would be required for a structure with a steady load. For the latter, a stress of 5 tons might be ventured with safety, while for the former 2½ tons would hardly afford the same measure of security. Some judgment has therefore to be exercised in determing the stress that wrought iron may be entrusted with, but in no case should it be burdened with a load producing a stress of more than 5 tons per sq. in. of sectional area.

CRANE CHAINS

Hoisting chains are of the short link *open* type, *i.e.*, without studs or stays. They may be safely worked to half the test load. The practical objections to a *stayed* link chain are its

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[1] Sir John Anderson's " Strength of Materials and Structures," page 53.

weight and its extreme roughness in working over pulleys. The *size* of a chain is reckoned as that of the diameter of the iron or steel bar from which the links are made.

The most useful sizes of crane chains range from $\frac{7}{16}$ to $\frac{3}{4}$ in. Above the latter size chains are apt to become rather stiff and clumsy, so it is better to use a wire rope along with a return or bottom-block.

Fig. 65 and the following table give the proportions of six sizes of chains. The load is taken for a maximum working stress of 5 tons per sq. in., but it is better to keep well below this figure, having regard to both safety and durability.

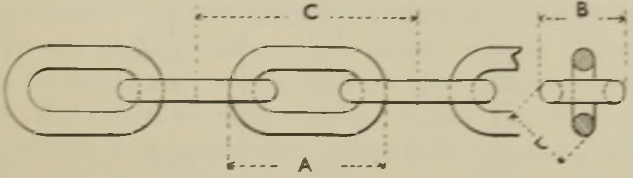

FIG. 65.—Proportions of Crane Chains.

Diam. of Iron	Length of Link A	Width of Link B	Pitch of Chain C	Diagonal D	Max. Load
In.	In.	In.	In.	In.	Tons
$\frac{3}{8}$	$1\frac{3}{4}$	$1\frac{1}{4}$	...	1	1·1
$\frac{1}{2}$	$2\frac{3}{8}$	$1\frac{11}{16}$	$2\frac{3}{4}$	$1\frac{3}{8}$	2
$\frac{5}{8}$	$2\frac{7}{8}$	$2\frac{1}{16}$	$3\frac{3}{16}$	$1\frac{5}{8}$ +	3
$\frac{3}{4}$	$3\frac{5}{8}$	$2\frac{1}{2}$	$4\frac{5}{16}$	2	4·4
$\frac{7}{8}$	$4\frac{1}{8}$	$2\frac{15}{16}$	$4\frac{11}{16}$	$2\frac{3}{8}$	6
1	$4\frac{1}{2}$	$3\frac{1}{4}$	5	$2\frac{5}{8}$	7·8

Anderson's simple rule (which was used at the Elswick Works), for the approximate working load in tons of wrought-iron chains, is to *square* the number of eighths of an inch in the diameter of the iron and to strike off the last figure as a decimal. This can be done quite easily mentally.

For example, in a 1-in. chain we have $8^2 \div 10 = 64 \div 10 = 6{\cdot}4$ tons as the greatest safe load.

Again, in the case of a $\frac{3}{8}$-in. chain, we have $3^2 \div 10 = 9 \div 10 = 0{\cdot}9$ ton as the greatest load at which it is advisable to work the chain, consistent with safety and durability.

One firm of chain makers give the following data regarding their highest quality of short-link wrought-iron crane chain. Their *working* loads (not tabulated here) are slightly under those given in Horner's table above, but are rather higher than the safe loads given by Anderson's simple mental rule.

Size of Chain	Approximate		Weight per Yard	Proof Load
	Length A	Width B		
In.	In.	In.	Lb.	Tons
$\frac{3}{8}$	$1\frac{13}{16}$	$1\frac{5}{16}$	5·75	1·63
$\frac{1}{2}$	$2\frac{3}{8}$	$1\frac{13}{16}$	9·4	3
$\frac{5}{8}$	$2\frac{7}{8}$	$2\frac{3}{16}$	14·5	4·63
$\frac{3}{4}$	$3\frac{9}{16}$	$2\frac{9}{16}$	19·5	6·75
$\frac{7}{8}$	$4\frac{1}{8}$	$2\frac{15}{16}$	25·5	9·13
1	$4\frac{3}{4}$	$3\frac{7}{16}$	33·6	12

Although short-link crane chains are now little used in conveyor work, the long-pitch wrought-iron chains have been employed extensively, especially when provided with malleable iron bearing blocks to form the Dodge cable chain. Some engineers, however, still utilize short link wrought-iron chains for supporting the buckets of double-strand cement elevators, especially in one or two South African Portland cement works.

The types of chains mostly used in conveyors and elevators are fully described in Chapter VIII of the author's book on "Conveying Machinery," to which reference should be made by those interested in that class of engineering work.

The Care of Chains.—Chains need periodical inspection and annealing to prevent or delay the setting up of crystallization in the iron. These operations should be repeated at least yearly in the case of cranes which are in constant use. The links are examined individually by inspection, and are tapped with a hammer to detect the presence of incipient cracks. If such are found to be present, then the faulty links must be cut out.

Annealing is done by heating the chains slowly in a furnace, free from contact with fuel, letting them remain at a red heat for a day or perhaps a day and a night, and then allowing them to cool down slowly. Afterwards they are reeved round a sheave and protected with a coat of boiled linseed oil applied with a brush.

Chains are very liable to become atwist, which tends to produce strains under the action of loads. The twist in new chains is removed by stretching the chain out on the ground and turning it about until the twist is taken out of it. When a chain gets twisted on its drum, the slack is run out and the twist removed by turning it at the bottom-block.

It is far better to wind crane chains on grooved drums than on plain drums. On the latter the chains are liable to override, especially at high speeds, when there results slipping off, surging, twisting and overstraining. By running in grooves, however, the chain is compelled to follow its proper course, besides which it is supported alternately on flats, instead of being strained across the angles.

Pitch or Pin or Gearing Chains.—These are more often *driving* chains than lifting chains. They are made to exact pitch or pin centres, in order to gear correctly with sprocket wheels. When used for the purpose of driving, such pin chains are made entirely of steel and are usually fitted with heat-treated bushes and rollers, being then styled bush or bushed roller chains. These details are omitted from lifting chains, however.

Though seldom used for lifting in England, yet steel pitch chains have been utilized to a considerable extent abroad. Instead of the usual drum or barrel, a cast iron or steel sprocket wheel winds up the chain and the slack side is guided into a box or container. In high-class work the wheel teeth are finished either by planing, milling or grinding, and they may be hardened as by the ‘Shorter’ process or by cyanide case hardening.

Steel pitch chain is used mainly to transmit power for short distances. Its chief applications are for connecting the driving axle to another driver on the trucks of portable cranes, and for operating the ground wheels of Goliath and gantry cranes from a shaft, running alongside the gantry beams, which is driven by the crab engines or by a motor.

Pin chains are used for transmitting motion to the wheel axles of some travelling cranes, when the centres are too far apart to be conveniently connected by toothed gears and shafts. This drive is positive, though flexible, and there is no reasonable limit to its applicability, the centres of the shafts varying from, say, 3 to 30 ft. or more.

Steel pitch chains are usually made by the crane makers themselves in *pairs* of thick links only, instead of in several thin laminæ, as shown in Fig. 66, which is the better plan. The *links* are stamped in dies under a press and drilled in jigs to the correct pitch. The *pins* are turned in a turret lathe, shouldered to space the links at the proper distance apart, and the ends, after assembling the parts, are riveted over either by hand or machine.

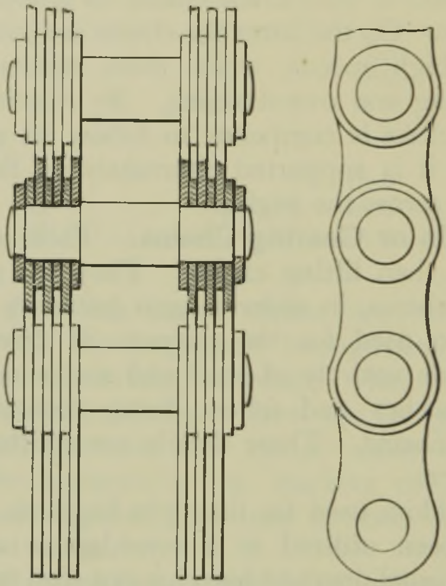

FIG. 66.—Steel Pitch Chain.

The small sizes of pitch chains are still made with single-plated links, but large ones should have laminated links, because greater safety is secured in this way than when using single thick links.

FIBRE ROPES

Hemp ropes have been used on cranes for well over a century. They are still used to a limited extent on quite light warehouse cranes, derricks and winches. Hemp ropes too are utilized as lifting slings for moderately heavy jobs.

Cotton ropes had a long vogue for driving overhead travellers and single-rail walking cranes, but have now been almost supplanted by electric motors. Their average life was much less than that of main driving ropes. Some reasons for this relatively short life were that the pulleys were not always large enough nor smoothly turned in the grooves, nor properly balanced. The diameter of pulleys for crane ropes should not be less than forty times the diameter of the rope.

Cotton and manila (or manilla) are better than hemp for crane ropes, because they are softer and more flexible; they also stretch less than hemp, are stronger and more durable. In America *manila*[1] is preferred to cotton. It comes from Manila, the capital of the Philippine Islands. Experience shows that equally good results are obtained with manila as with cotton ropes if equal care is bestowed on the size and shape of the pulleys and on the lubrication of the ropes. Four strands of rope are preferred to three.

In the manufacture of manila ropes the fibres are first spun into a yarn twisted in a right-hand direction. From 20 to 80 of these yarns are then twisted together in the opposite direction, the precise number depending on the size of the rope. Four of these strands are then twisted together right hand to form a rope. The effect of pull on the rope is to cause these opposite twists to neutralize one another, or nearly so. It is because it is impossible to make these neutralize each other exactly that the twist has to be taken out of a new rope. Some of it comes out in course of the wear of the first day or two, and the rope stretches; but afterwards its length will remain nearly constant unless the rope is overloaded.

Ropes wear both externally and internally. The *external* wear is due to the friction between the rope and its pulley and the constant bending of the fibres round the pulleys. The *internal* wear is due to the friction of the fibres over each other, as the rope is alternately bent and straightened. On opening a badly worn rope the result of the internal friction is seen in the form of powder. To reduce this the yarns of good manila ropes are lubricated with plumbago and tallow, besides being rendered partly waterproof.

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[1] This is a vegetable fibre obtained from the leaves of a variety of wild banana. It does not readily decay.

A frequent cause of failure in ropes was too short a splice or a splice not evenly made. A short splice of 3 ft. will inevitably be pulled out ; its length should be 6 to 9 ft. On the evenness or otherwise of the splice its durability depends. It should not be larger or smaller than the rest of the rope. Crane ropes must not be overloaded ; a working load of one-twentieth of the breaking strength at the splice being considered good practice.

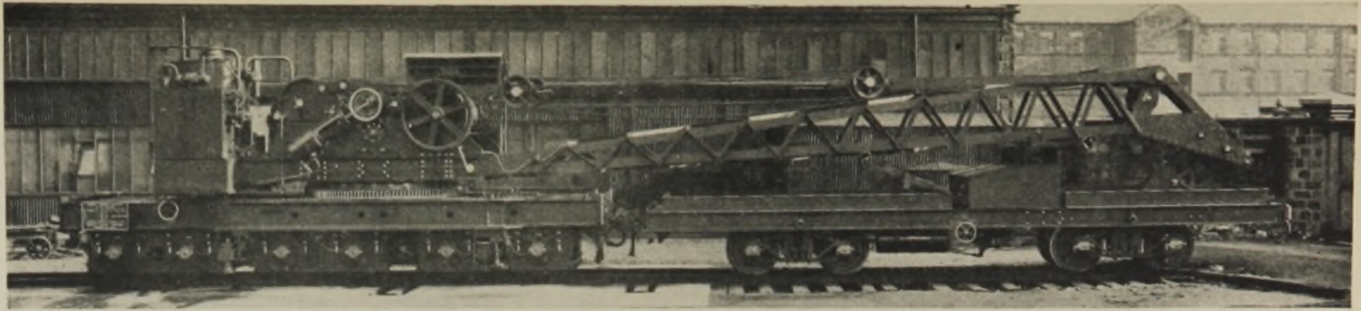
Cotton ropes driving overhead travellers were styled either high-speed or slow-speed ropes according as they ran at about 4000 ft. per min. or nearer half that speed. The slower running ropes were the more durable and also less noisy in operation, though their first cost was higher, because they were of larger diameter for a given power to be transmitted.

Historical Note on Rope-driven Cranes.—A little book dated 1864 in the author's possession contains an interesting note headed " An Improved Power Travelling Crane." This book consists mainly of a list of wheel patterns belonging to the old Manchester firm of engineers and millwrights of Wren & Hopkinson, once a flourishing concern before the era of extreme specialization but now, alas, extinct. It was the early training ground of the two famous brothers, Doctors John and Edward Hopkinson, their father, Alderman John Hopkinson, having been head of the firm. Wren and Hopkinson's were one of those truly *general* engineering firms which have now become so rare ; for not only did they make hand and power cranes, but also steam engines, hydraulic presses and pumps, sawmill machinery, newspaper printing machines, cotton and silk machinery and much else. This historical note throws a side-light on the current crane practice of seventy-five years ago, reading as follows :—

" The improvement consists in transmitting power by an endless cord, driven from any stationary source at a high velocity, so as to give motion to any part of the crane by bringing the cord in contact with grooved pulleys of different diameters, so giving the power either for traversing longitudinally and transversely or for hoisting.

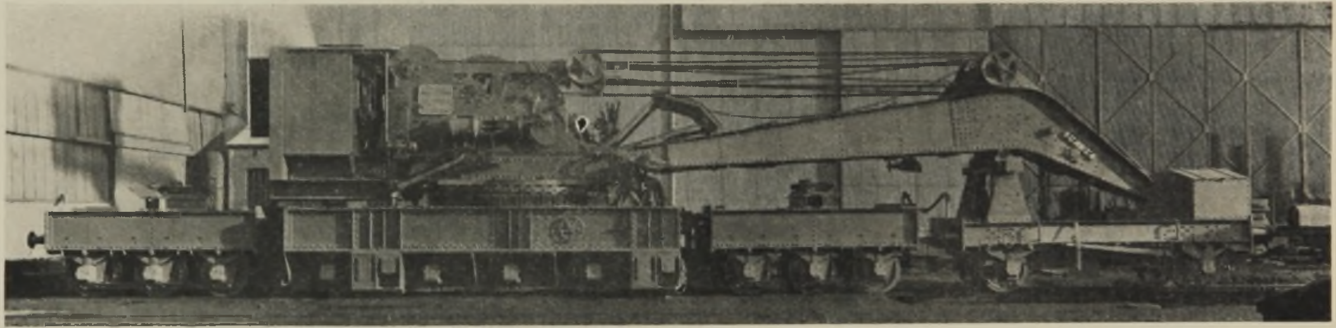
" The advantages of this system over an ordinary power crane are—extreme lightness in all its parts, not having to sustain the weight of an engine and boiler, with fuel and water ; also dispensing with the nuisance of smoke and dirt, as well

PLATE 11



Joseph Booth & Bros., Rodley, Leeds.

20-TON BRIDGE ERECTION CRANE WITH LONG JIB ON MATCH-TRUCK.



Ransomes & Rapier Ltd., Ipswich.

STEAM BREAKDOWN CRANE WITH STOKES' RELIEVING BOGIES.

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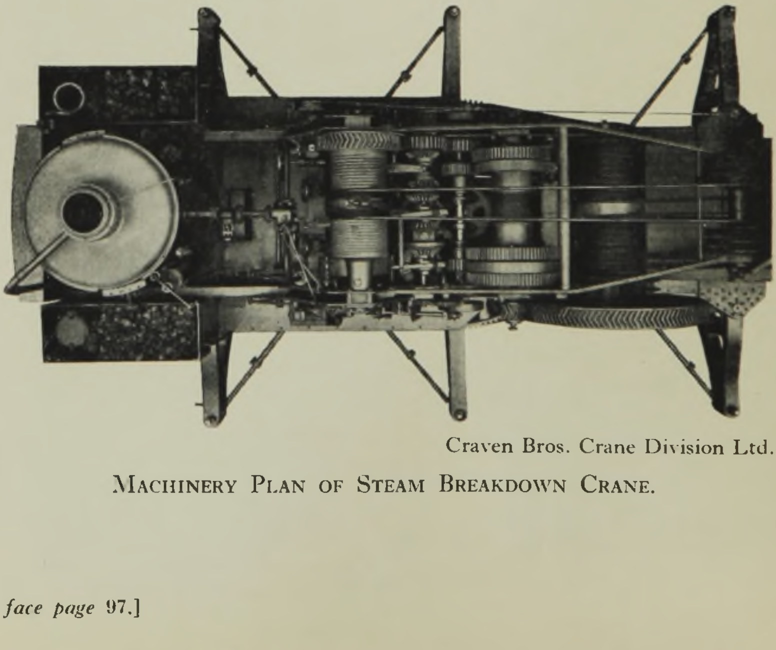
Craven Bros. Ltd.

40-TON CRANE.

Cowans, Sheldon & Co. Ltd.

120-TON CRANE.



Craven Bros. Crane Division Ltd.

MACHINERY PLAN OF STEAM BREAKDOWN CRANE.

as danger from fire, in those cases where the power is applied direct; or in cases where the power is derived from any stationary source, all grooved or square shafting is dispensed with, effecting economy both in friction and weight.

" It has also the advantage of being readily used as an ordinary hand crane, should the engine or other motive power be at any time unavailable, without interfering with the efficiency of the power system; handle shafts being provided to all the movements, with both single and double purchase, also brake gear for lowering.

" The advantages over the hand-travelling crane are—increased speed and smoothness of motion, both in traversing longitudinally and transversely, as well as in lifting, which movements may all be accomplished simultaneously; lowering with greater ease and safety than by means of a hand brake; also performing all the work by one man or boy instead of six, or in cases of heavy lifts, eight men.

" These travelling cranes are suitable for dockyards wharfs, ironfounders, engineering establishments, especially marine and locomotive, where heavy lifts are constantly required, also for sawmills and timber yards, where risk of fire renders steam travelling cranes objectionable."

So much for the crane practice of seventy-five years ago. But that early form of rope power travelling crane still survives in a few places. Only a few months ago the author noticed a very old crane of this type driven by a fly-rope still at work over a stone yard near the docks at Bristol.

Despite the drawbacks of the overhead steam-driven traveller, as enumerated in the above note of 1864, it is interesting to remark that the same firm some twenty-five years later constructed such a crane of 66 ft. span for the Cheshire Lines Railway, complete with steam engine and boiler mounted on a travelling crab. It was erected in the open air at the Huskisson Dock, Liverpool. The making of the detail drawings for this crane was an early experience of the author.

WIRE ROPES

Wire rope began to be introduced into crane work about the year 1880, since which time it has become increasingly used alike for the heaviest as for the lightest loads. It occupies much less space than chain of equivalent strength, and it is safer because it gives warning by stretching before fracture. But steel-wire rope needs much larger drums than chain, in order to avoid the risk of stretching the outer strands when the rope is being coiled around them.

The least diameter of a drum or a sheave around which a wire rope should be wound is *thirty* times the girth or circumference of the rope. A wire rope occupies about one-ninth of the space on a drum that a chain of equal strength does, and it makes less noise when hoisting. It is useful to note that a steel-wire rope of 3 in. girth weighs 7 lb. per fathom of 6 ft., whereas a chain of equal strength weighs 30 lb. and a hemp rope 19 lb. per fathom.

A rope is made up of wires laid into a strand and these strands are twisted together into a rope. Either hemp or wire cores or centres may be laid in each strand and in the complete rope. Wire ropes are commonly referred to or labelled by the diameter of the circumscribing circle in inches coupled with two figures denoting the number of strands and the number of wires in each strand respectively, thus $\frac{3}{4}$ in. × 6 × 24.

A kind of rope that was much used is composed of six strands, each of twelve wires, enclosing a hemp core, the whole being laid round a hemp heart. This is styled a compound rope. In order to get a higher degree of flexibility the later practice is to use a larger number of wires (as 24 or 37) of smaller size, the hemp cores being reduced or omitted altogether, excepting the centre one or heart. The breaking strength of the steel wire is about 90 tons per sq. in., though a considerably higher tensile strength is obtainable if desired. But wire of very high tensile steel is less flexible and demands a bigger drum.

The *lay* of a wire rope denotes the direction in which the strands are laid or twisted. This may be either right hand or left hand. In the regular lay the constituent wires are twisted round to form six *left*-hand strands, whereas the strands themselves are twisted to form a *right*-hand spiral rope, comparable with a six-start multiple thread in a screw. Thus the individual twists are in opposite directions. In *Lang's* lay the twist of the wires and the twist of the strands are both in the same direction, usually right-handed.

The Care of Wire Ropes.—Galvanizing is adopted for standing ropes but not for running ropes, which should be kept well oiled with linseed or other oil and occasionally greased. Lubrication prevents corrosion and reduces internal friction. Neutral oils and greases must be used.

Care must be taken to avoid twist, kinks and overlaps. In unwinding a rope, therefore, it must not be taken from the coil, but run off from a reel. To prevent overlap, hoisting drums are grooved for the rope to lie in, and it is best to have only one coil on a drum. The ends of ropes are fastened to a thimble (Fig. 67) both for the anchorage to the drum, as shown in Fig. 57, and for the connection to the crane hook.[1]

There is an important difference between a hemp and a wire rope in the length of the *splice*. From 6 to 9 ft. is long enough for the former, whereas the splice in a steel-wire rope varies from 30 to 60 ft. in length. When a rope is closed in the *opposite* direction to that in which the strands are laid, a length of 15 ft. is unlaid at each end to form a splice, but when closed in the *same* direction, the more ample length of 30 ft. is unlaid at each end for splicing.

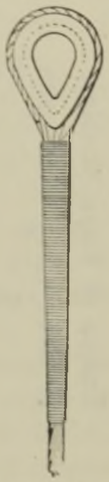


Fig. 67. Wire-rope Thimble.

When the Forth Bridge was under construction it was found that in certain hoists having pulleys with their grooves turned and polished, and with side play for the ropes, the latter wore out rapidly in from six to twelve weeks. But the simple expedient of lining the pulleys with *wood*, together with lubricating the ropes properly, entirely remedied the mischief. The ropes then ran for two or three years, in fact until the bridge was completed, with scarcely any signs of wear.

Ropes should be *stored* under cover in a clean, dry place and be raised clear of the ground, avoiding contact with dirt, ashes and coke breeze. A periodical examination of ropes in store should be made, and the protective coating of rope-dressing occasionally renewed. When uncoiling wire

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[1] Bulldog *grips* are used as a convenient alternative to splicing a wire rope round a thimble, three or four grips per joint being generally used. For details of standard grips see B.S.S. No. 462 (1932).

ropes, they should be paid out, without slack, from the reel or coil in a straight line, in order to prevent the possibility of kinking or disturbance to the lay of the rope.

Durability of Wire Ropes.—The great importance of using flexible ropes, together with drums and sheaves of large diameter, is emphasized in a British Standard Specification for round standard steel wire ropes (No. 302, 1938), where an instructive graph is given, indicating the life of ropes, of which a simplified form is shown in Fig. 68. Here the life or durability is not expressed in so many months but in the number of times that a running rope is bent or deflected (usually 90°) round a pulley before failure of the rope takes place.

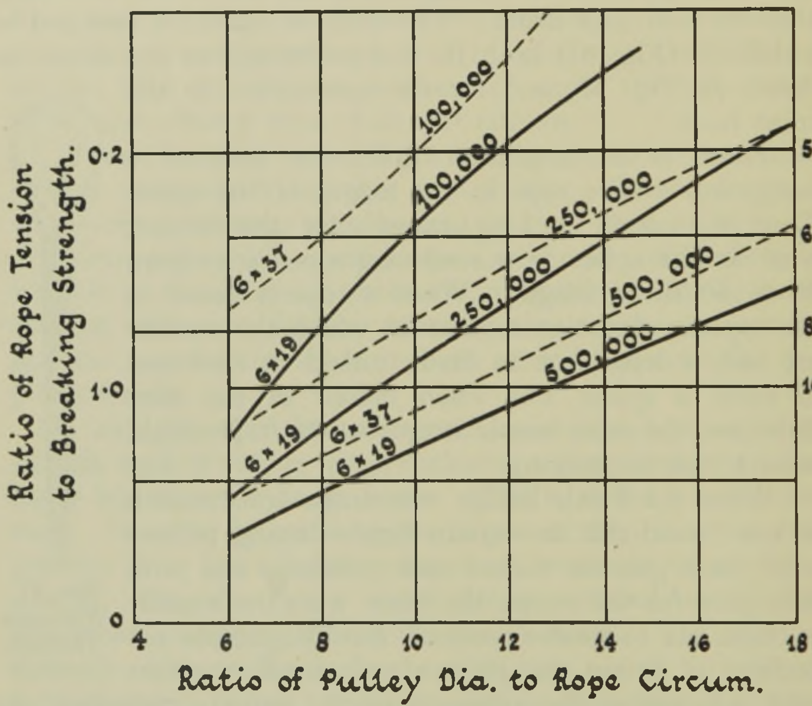

FIG. 68.—Graph of Wire-rope Life.

In plotting these curves the *base* is taken to represent the ratio of the diameter of the pulley to the circumference or girth of the rope, this ratio varying from 6 to 18. The ordinates or verticals represent another ratio, namely the tension on the rope divided by the breaking strength of the rope. Further, the four horizontal lines marked 5, 6, 8 and 10 indicate the different factors of safety, or ratios of the breaking strength to the working tension on the rope.

If, for example, on a 6 × 19 rope we allow a factor of safety of 8, then in order to obtain a life of 100,000 cycles with the rope working under the very best conditions, we must have a base ratio of 7·9, while for a life of 500,000 cycles a base ratio of 15·7 is necessary. This means that in the first case the pulley must be 7·9 times the circumference of the rope and in the second case 15·7 times. Thus for a rope of 3-in. girth we require to use pulleys (drums or sheaves) of 23·7 and 47 in. diameter respectively, at the very least.

As these are rather big sizes for economy of construction a more flexible rope is indicated, say 6 × 37, for which the graph gives base ratios of 5·2 and 13·4 for cycle numbers of 100,000 and 500,000 respectively. Using this very flexible rope the pulley sizes then drop to 5·2 × 3 or 15·6 in. and 13·4 × 3 or 40 in. respectively for the same life of rope, as compared with the 23·7 and 47 in. pulleys needed with the less flexible 6 × 19 wire rope.

These pulley sizes are still bigger than is customary in crane practice, which means that the life of wire ropes is relatively short. On this point a useful foreword to B.S.S. 302 (1938) remarks : " It is recognized that the sizes of drums and pulleys used in existing practice are in many cases smaller than those recommended, and also that it may be expedient to use smaller sizes to save costs in other directions. But it should be realized that a serious reduction of rope life will result, and it is certain that more satisfactory results would be obtained if the sizes of drums and pulleys conformed to the sizes herein recommended. It is advisable, whenever possible, to make the pulleys larger than the drums."

Numerous experiments and practical experience have proved that *reverse bends* are very detrimental to the life of a rope, and therefore they should be avoided wherever possible in arranging the lead of a rope. For *grooved* drums and pulleys the angle of lead should not exceed 5° or 1 in 12. This angle should be reduced for *plain* drums, which are certainly detrimental to the life of wire ropes. Also the use of overlapping ropes is discouraged.

Wire ropes in service should be examined from time to time and their condition noted, as they should never be run until there is a breakage or even the risk of one. Moreover a critical inspection of the grooves of drums and pulleys is necessary before installing new ropes. A groove that has been deepened by rope wear is apt to cause premature failure of a new rope. This trouble can be avoided by taking the precaution to turn the faulty groove to the correct shape before fixing the rope.

Material and Strength of Wires.—The round wire used in the manufacture of steel ropes to the British Standard Specification is drawn from steel billets made by the acid open-hearth process. It is produced in two grades or qualities. In grade A, or special acid quality, the amount of either sulphur or phosphorous present is limited to a maximum of 0·04 per cent., whereas in grade B, or acid quality, the percentage is limited to 0·05.

The actual breaking strength of wire varies from 80 to 120 tons per sq. in. of section, the strongest wire being the least flexible. A trade practice has grown up of styling wire ranging between 80 and 90 tons tensile " best patent steel," whereas one calls wire in the range 90 to 100 tons by the name of " special improved patent steel." Again, the trade description of wire in the range 100 to 110 tons is " best plough steel," whereas the strongest wire, ranging from 110 to 120 tons tensile, is labelled " special improved plough steel."

In this curious progression of adjectives, one gradually advances from ' best ' to even better, then to better still and finally to ' special.' Merely good steel is completely ignored. Such loose nomenclature is reminiscent of the ' superlative ' language so freely employed by advocates of patent medicines !

The following short composite table has been compiled from several tables given more fully in B.S.S. No. 302 (1938). It gives the weight and the breaking load of two constructions of best plough steel wire ropes, the steel having a tensile strength of 100 to 110 tons per sq. in. The strength of the 6×24+fibre rope construction is slightly lower than that of the 6×37 rope, say roughly 5 per cent.

Composite Table of Wire Ropes

Girth[1] of Rope	Approximate		Breaking Load	
	Diameter	Weight per 100 Ft.	6 × 19 Rope	6 × 37 Rope
In.	In.	Lb.	Tons	Tons
$1\frac{1}{8}$	$\frac{3}{8}$	21	4·1	4·2
$1\frac{5}{8}$	$\frac{1}{2}$	43	9·0	8·4
2	$\frac{5}{8}$	66	13·7	13·2
$2\frac{3}{8}$	$\frac{3}{4}$	92	19·4	18·0
$2\frac{3}{4}$	$\frac{7}{8}$	123	25·3	24·7
$3\frac{1}{8}$	1	168	33·9	32·4
$3\frac{1}{2}$	$1\frac{1}{8}$	217	43·8	39·7
$3\frac{7}{8}$	$1\frac{1}{4}$	262	53·8	49·4
$4\frac{3}{4}$	$1\frac{1}{2}$	392	79·5	74·1

[1] *Girth* here means the circumference of the circumscribing circle of the rope section.

CHAPTER IX

HOOKS AND BOTTOM-BLOCKS

THE hook of a crane supports its load by means of a sling. This hook is generally open and *single*, though many heavy cranes have *double* hooks. Some very light hooks are attached directly to their chains, as in Fig. 69, but more connect up through an intermediary swivel, and are termed swivel hooks. In Fig. 70 the swivel attachment of a hook to a chain is seen, also a counterbalance ball weight by which the slack of the hoisting chain is overhauled when no load is being lifted.

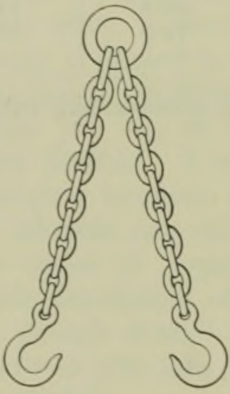

FIG. 69.—Double-chain Sling.

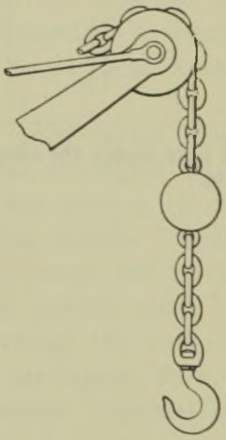

FIG. 70.—Swivel Hook and Weight.

Hooks were formerly always made of the best wrought iron, bent round to retain the greatest strength of the fibres ; but many are now steel drop forgings, unless of unusual size.

Shank Hooks.—Much valuable information on the subject of crane hooks is given in the B.S.S. No. 482 (1933), for wrought-iron and mild-steel hooks, including tables of proportions and dimensions for no less than five types.

Though hooks of the so-called *trapezoidal*[1] cross section (Fig. 71) are recommended as normal standards, an alternative is given for hooks of round cross section (Fig. 72), which some users prefer for small working loads up to 5 tons.

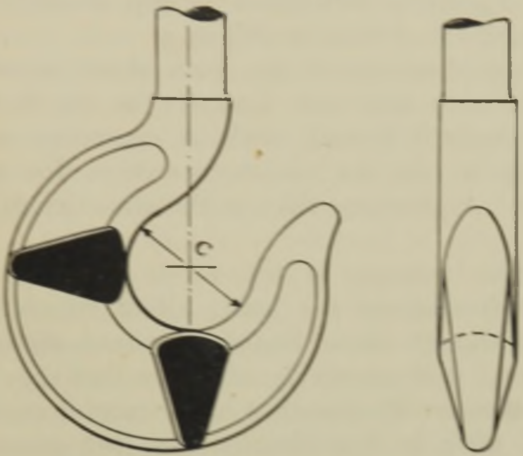

FIG. 71.—Trapezoidal Shank Hook.

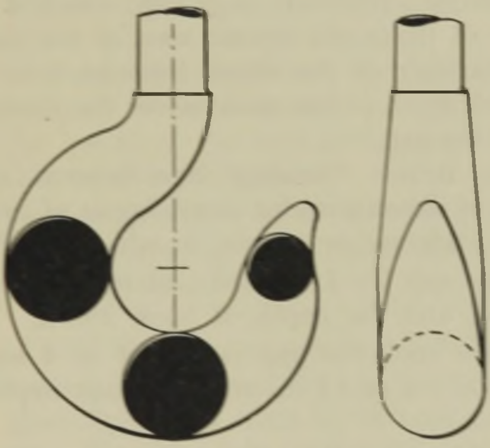

FIG. 72.—Round Shank Hook.

A table gives complete dimensions for shank hooks of trapezoidal or flattened section, for safe working loads from ¼ ton up to 75 tons. In preparing this table the basis unit is the diameter of the gap C, which is taken to be 1½ times the square root of the *load* expressed in tons. Thus for a 1-ton

---

[1] Really a rounded triangular section. It is a rather cumbrous name.

load the *gap* is $1 \cdot 5$ in. diameter and for a 25-ton load it is $1 \cdot 5 \times \sqrt{25}$ or $7 \cdot 5$ in. The diameter of the shank is taken as $0 \cdot 55$ of the gap C, which for a 25-ton load becomes $0 \cdot 55$ of $7 \cdot 5$ or $4\frac{1}{8}$ in. The total depth of the hook below the shoulder of the shank is given as $2 \cdot 75$ times the gap, which for a 25-ton hook becomes $2 \cdot 75 \times 7 \cdot 5$ in. or $20\frac{5}{8}$ in.

The tabular diameter of the hook shank is sufficient to allow reduction to the core diameter at the bottom of a standard Whitworth thread, without exceeding a stress of 3 tons per sq. in. on the minimum section due to the safe working load. A generous fillet at the shoulder of the shank is important.

In a similar manner to the above one can determine fifteen other dimensions per hook, all of which have been tabulated. Although these British standard dimensions are not compulsory, it is extremely advisable that they should be adopted, for they are the result of much careful work.

A second table in Specification No. 482 gives complete dimensions of alternative shank hooks for small loads up to 3 tons and having a relatively large gap, which is taken not as $1 \cdot 5$ but as $1 \cdot 84$ times the square root of the *load*. In this design the diameter of the shank becomes $0 \cdot 45$ of the gap, while the total depth of the hook below the shoulder is taken as $2 \cdot 46$ times the gap.

The same British Standard Specification also contains another table of dimensions for shank hooks of *circular* section (Fig. 72) for loads up to 5 tons, in which the basic dimension is still the gap $C = 1 \cdot 5\sqrt{\text{load}}$. Here the shank diameter becomes $0 \cdot 55C$ and the depth of hook $2 \cdot 67C$. Thus in the case of a 4-ton hook the gap is $1 \cdot 5\sqrt{4}$ or 3 in., the shank diameter is $0 \cdot 55 \times 3$ or $1\frac{5}{8}$ in. and the hook depth is $2 \cdot 67 \times 3$ or 8 in.

One should note that the volumes and weights of geometrically *similar* hooks vary as the cubes of any corresponding linear dimension as, say, the diameter of the gap C.

Moreover, since $C = 1 \cdot 5\sqrt{\text{load}}$,

or $C = \text{a constant } \sqrt{W}$,

then $C \propto W^{\frac{1}{2}}$

and $C^3 \propto W^{\frac{3}{2}}$.

Hence the *weights* of similar hooks vary as the $\frac{3}{2}$th power of their safe working loads. Thus the weight of a 25-ton hook is to the weight of a 4-ton hook as $25^{\frac{3}{2}}$ is to $4^{\frac{3}{2}}$, or as 5^3 is to 2^3, or as 125 is to 8, or as 16 to 1 nearly.

As regards the quality of *material*, all crane hooks should be made from either best Yorkshire iron or open-hearth steel, and normalized by heat treatment after forging. This process consists in uniformly heating the hooks in a furnace to a temperature throughout of about 1000° C. in the case of wrought iron and about 900° C. for mild steel. The hooks are then drawn out of the furnace and allowed to cool slowly in still air. After treatment every hook is subjected to a proof load of *twice* the safe working load, which it should withstand without showing any appreciable permanent set.

Eye Hooks.—In addition to the *shank* hooks a geometrically similar series of *eye* hooks has been worked out by the British Standards Institution in two types, one for use with welded rings or joining links and the other suitable for using with shackles having removable pins. The former type has a bell-mouthed eye and the latter a parallel hole, otherwise they are alike, as seen in Fig. 73.

All the standard hooks, whether with shank or with eye, have been designed so as to induce an equal stress on the material at the inside of the mid-section at the back of the hook, under the rated working load.

In the *round* section eye hooks the relation $C = 1{\cdot}5\sqrt{W}$ still holds good, whereas in the trapezoidal eye hooks the constant is increased from 1·5 to 1·84, thus giving a wider gap.

The value 1·84 also corresponds to the relation $C = 4{\cdot}5d$, where d is the nominal diameter of the bar iron in the complementary short-link crane chain to be used as a sling along with the hook. Thus for $\frac{1}{2}$-in. chain the gap C in the eye hook becomes $4{\cdot}5 \times 0{\cdot}5$ in. or 2·25 in.

In all the flattened or trapezoidal hooks the principal cross section (at the *back* of the hook) and the vertical section (at the *bottom* of the hook) are equal and similar, for a given load, save that the crown radius at the vertical section is slightly less, in order the better to accommodate sling fittings. The maximum cross section occurs midway between the principal and the vertical sections, and is about 10 per cent.

deeper, thus adding appreciably to the stability of the hook under an excessive load.

In compiling Table III in B.S.S. No. 482 for eye hooks

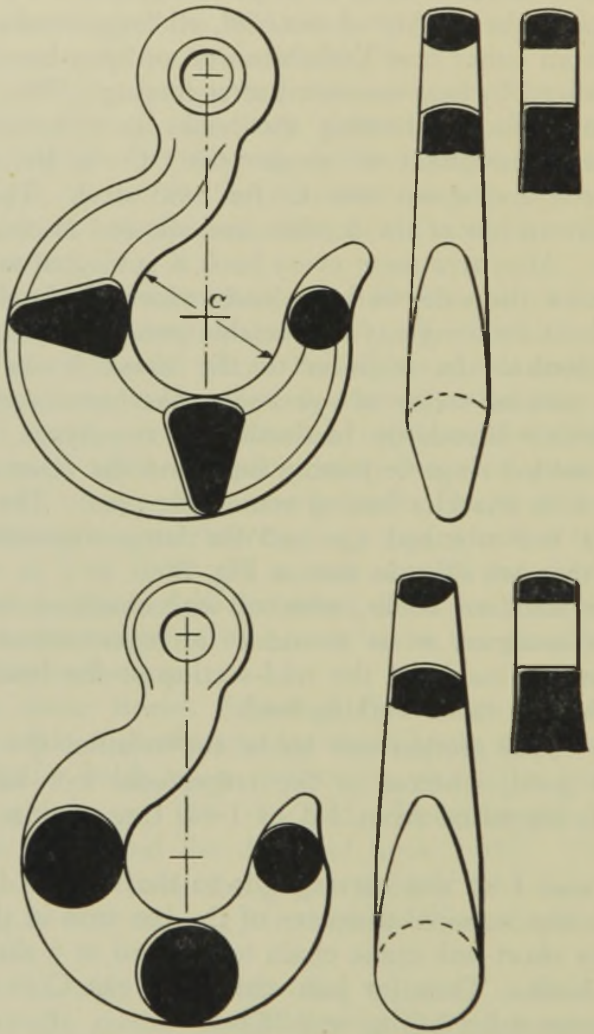

FIG. 73.—Standard Eye Hooks.

of trapezoidal section, suitable for use with short-link crane chains ranging from $\frac{5}{16}$ to $1\frac{1}{2}$ in. diameter, the unit is taken as the nominal diameter of the bar. Taking the case of a 1-in. chain, having a recommended working load of 6 tons, the gap $C = 4\cdot 5d = 4\cdot 5 \times 1$ in. $= 4\frac{1}{2}$ in. Also the extreme depth of the hook is $14{\cdot}83d = 14{\cdot}83 \times 1$ in. $= 14\frac{7}{8}$ in. Again the diameter of the bell-mouthed hole in the eye is $1{\cdot}5d = 1{\cdot}5 \times 1$ in. $= 1\frac{1}{2}$ in., while the diameter of the parallel hole for a shackle pin is $1{\cdot}6d$ or, say, $1\frac{5}{8}$ in., in the chosen case of a 1-in. chain.

Finally, Table V in the same standard specification gives dimensions of eye hooks of *circular* section suitable for loads ranging from $\frac{1}{4}$ to 5 tons. Here the unit is not the china diameter but the width of the gap $C = 1{\cdot}5\sqrt{W}$, as in the shank hooks. Thus for a safe working load of 4 tons we have $C = 1{\cdot}5\sqrt{4} = 1{\cdot}5 \times 2 = 3$ in. as the gap diameter. Also the extreme depth of the hook here becomes $3{\cdot}57C = 3{\cdot}57 \times 3$ in. $= 10{\cdot}71$ in. or, say, $10\frac{3}{4}$ in. Again the diameter of the bell-mouthed eye hole becomes $0{\cdot}44C = 0{\cdot}44 \times 3$ in. $= 1{\cdot}32$ in. or, say, $1\frac{5}{16}$ in. Lastly the diameter of the parallel hole is $0{\cdot}5C = 0{\cdot}5 \times 3$ in. $= 1\frac{1}{2}$ in.

It is hoped that the above analysis and interpretation of this important British Standard Specification on crane hooks will prove helpful both to those who possess it and have not yet carefully studied it and also to those who are not in a position to refer to the specification itself.

It is interesting to note that on testing to destruction several specimen hooks made to this specification, not one hook failed at a load below 5 times the rated safe working load, thus proving its adequacy.

Liverpool or 'C' Hooks.—The 'C' type of hook is much used on light cargo handling cranes, the shape (Fig. 74) being specially designed to prevent fouling of the hook during hoisting and lowering operations around ship's hatchways. It is a relatively cheap hook, used without a return block. There is an eye attachment to the terminal fitting, suitable for use either with shackles or with joining links.

To counteract the tendency of a suspended hook to spin, especially when attached to a wire rope, a ball-bearing *swivel* is fitted just beneath the wire rope and above the overhauling weight, as shown in Fig. 75. This fitting permits free rotation of the hook.

The section of the hook is trapezoidal and the strongest available. In designing a series of 'C' hooks the stress across the principal section at the inside of the hook, due to the rated working load, is kept uniform throughout the entire series.

The primary relation adopted is $C=1{\cdot}84\sqrt{W}$, where C (in.) is the bed diameter and W (ton) is the rated working load. A few other proportions may be noted. The overall depth A of the hook is $3{\cdot}94C$, the maximum width M of the cross section is $0{\cdot}55C$, the width S at the eye is $0{\cdot}4C$ (which is also the diameter of the parallel hole) and the diameter T of the bell-mouthed hole is $0{\cdot}36C$.

The B.S.S. No. 591 (1935) contains a complete series of proportions and a full table of dimensions derived therefrom, of which a few selected figures are given below :—

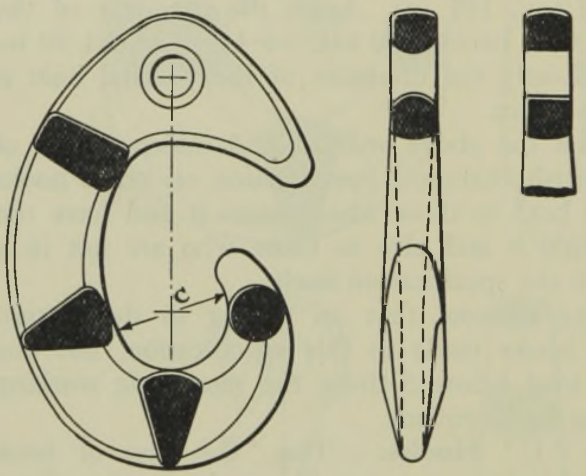

FIG. 74.—Liverpool or ' C ' Hook.

FIG. 75. Ball-bearing Swivel.

W Load	C Basis	A Depth	M Width	S Eye	T Hole
Tons	In.	In.	In.	In.	In.
1	$1\frac{13}{16}$	$7\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{11}{16}$
3	$3\frac{3}{16}$	$12\frac{9}{16}$	$1\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{8}$
5	$4\frac{1}{8}$	$16\frac{1}{4}$	$2\frac{1}{4}$	$1\frac{5}{8}$	$1\frac{1}{2}$
10	$5\frac{13}{16}$	$22\frac{7}{8}$	$3\frac{3}{16}$	$2\frac{5}{16}$	$2\frac{1}{8}$

As regards the *weight* of ' C ' hooks, this may be taken as w (lb.)$=3{\cdot}62W^{\frac{3}{2}}$.

Thus a 1-ton hook weighs 3·62 lb., while a 5-ton hook weighs $3{\cdot}62 \times 5^{\frac{3}{2}} = 3{\cdot}62 \times (2{\cdot}24)^3 = 41$ lb.

It should be noted that under severe tensile static tests no 'C' hook failed at a load less than $7\frac{1}{2}$ times the rated working load, so that the factor of safety is ample.

BOTTOM-BLOCKS

A bottom-block,[1] or return-block, is used on every crane save those of low power, in order to increase the lifting capacity without unduly increasing the size of the chain or of the wire rope sustaining the load. Essentially a block comprises a swivelling hook, a crosshead, cheeks and at least one sheave.

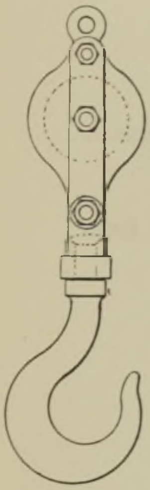

FIG. 76.
Simple
Bottom-block.

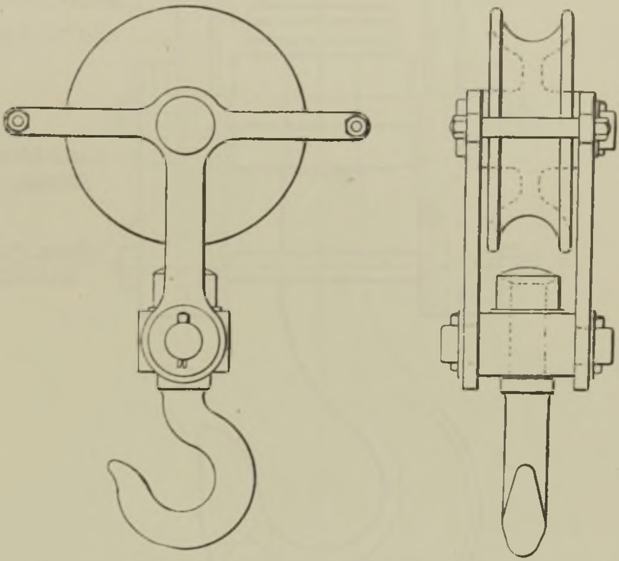

FIG. 77.—Light Single Block.

Fig. 76 shows a simple block formed of two side plates of sheet steel stiffened with side bars or links, which take the load and are kept apart by distance-pieces, while the hook swivels in a block or crosshead through which its neck or

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[1] The terms hook-block, fall-block and hoist-block are also used as synonyms. The old name of snatch-block is now used in a somewhat different sense for a particular kind of block fitted with a hinge and lock.

shank passes, the end of the shank being secured by riveting over, or by a nut and pin.

In the design of light block illustrated by two views in Fig. 77 the cheeks take the form of two forged crosses, spaced apart by distance-pieces. The hook swivels in a steel cross-head with turned trunnions, this also forming a distance-piece. The shank of the hook is screwed into a thick, round nut and riveted over for additional security. The chain sheave turns on a fixed centre pin.

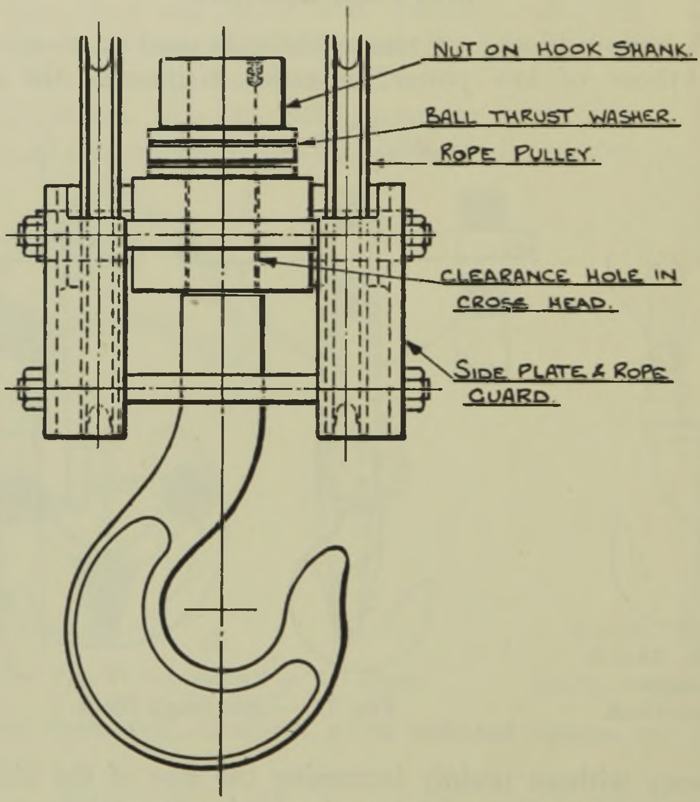


FIG. 78.—Short Bottom Block. (From Barson).

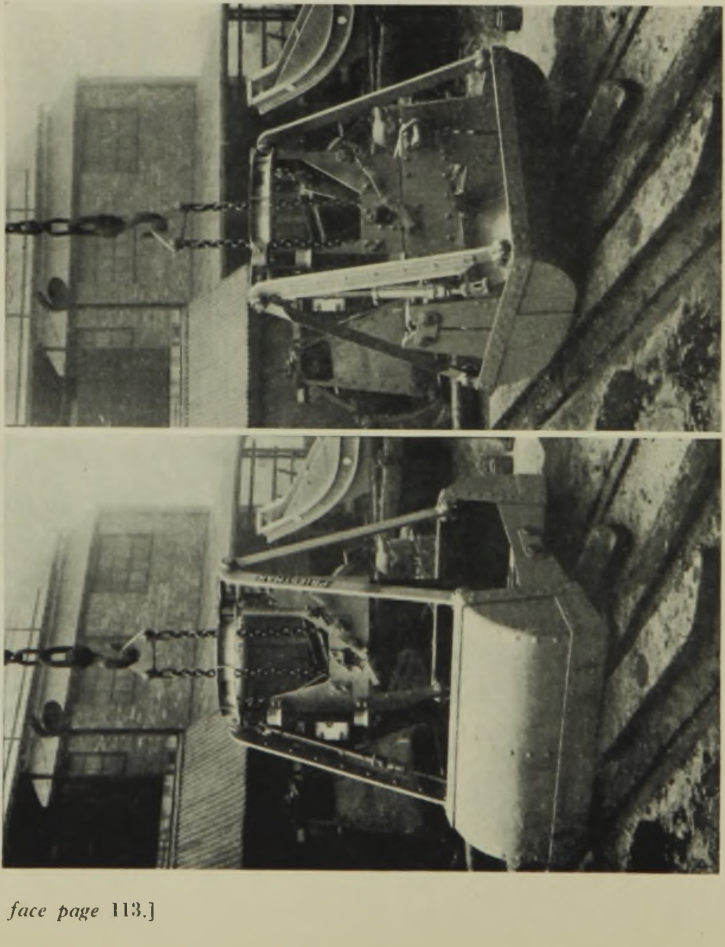
Fig. 78 shows a compact and economical block suitable for lifting on four parts or plies of rope. In this design both hook and sheaves are carried on a steel crosshead through which passes the shank, whilst the two sheaves turn on its side trunnions. The side plates are connected by four distance stays, which serve the dual purpose of holding the

VARIOUS TYPES OF CHAIN SLINGS.

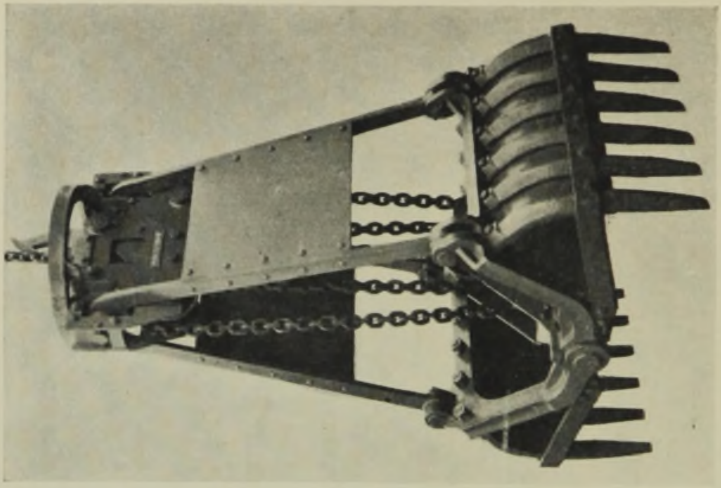
Herbert Morris Ltd.

BOX, CASK AND LOG SLINGS.

PLATE 14



HOOK-ON DUMPING GRAB.



TINE GRAB FOR CLAY.

Priestman Brothers Ltd., Hull.

To face page 113.]

parts together and of preventing the rope from leaving the sheaves in the event of the block being lowered down to the floor. The shank nut rests on a ball-thrust washer, in order to ensure easy rotation of the hook.

Fig. 79 indicates in a perspective view such a block suspended from the rope drum and the compensating sheave of an overhead crab. Here the wire rope has six bends and no reverse bends, the latter being highly detrimental to the life of a rope. For the sake of rope durability the sheaves of crane-blocks should be made of large size, at least 20 times and preferably 24 times the diameter of the rope. Even 30 diameters of the rope have been recommended for the sheaves of steelwork cranes constantly engaged on severe duty.

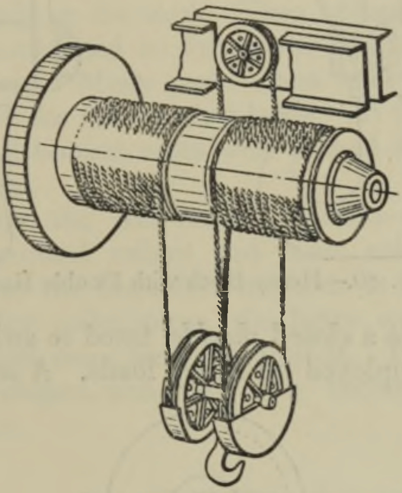


Fig. 79.—Block and Drum with the Best Rope Reeving.

In Fig. 80 is detailed a heavy type of block with three sheaves for six parts of wire rope. Here we have forged steel links, which at the top take the sheave pin and at the bottom receive the turned necks or trunnions of the swivel-block, while thin side plates and distance-pieces stiffen the whole arrangement. The rope sheaves are separated by intermediate plates, which are spaced apart by short pieces of tube.

In this example the hook is *double*, a form sometimes styled a ram's horn hook. Such a double hook is often adopted in very heavy cranes, as it permits the use of two sling chains better than a single hook does. Ball-bearing thrust washers are introduced to facilitate turning the loaded hook.

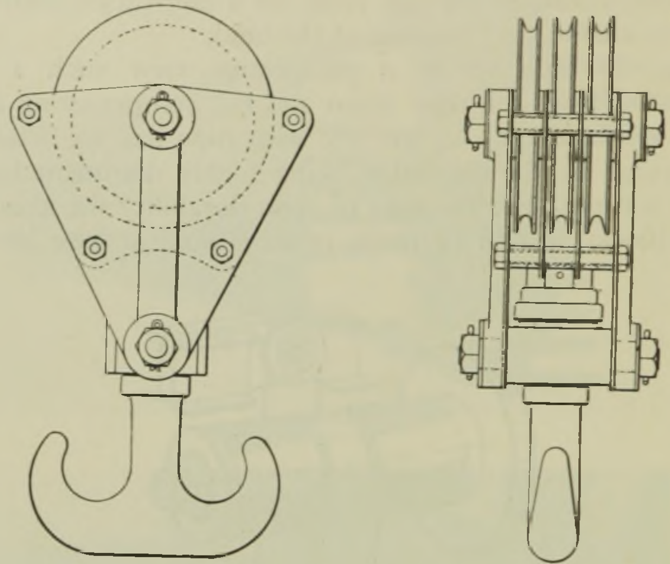


Fig. 80.—Heavy Block with Double Hook.

Fig. 81 shows a closed *shackle*, fitted to swivel in its block, as sometimes employed for heavy loads. A separate auxiliary

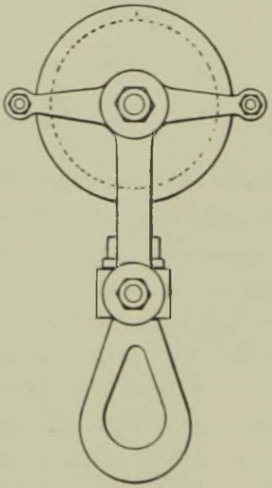


Fig. 81.—Closed Shackle Block.

shackle of the open-pin type is often inserted in a main shackle to carry a sling chain. Then there is no risk of the sling slipping out, as may happen in the case of an open-sided hook.

Such a shackle takes the place of a safety hook, *i.e.*, one in which the open side is closed by a spring contrivance after the insertion of the sling, which prevents the latter from coming off the hook, a possibility in some cases where the load may tilt or touch the ground. A similar shackle is used for attaching the return chain at the crane end, as at the top of a jib.

Nowadays most cranes have their hooks made to swivel on ball races, in order to minimize the friction. It used to be a terrible task to slew the loaded hook of a heavy crane with men pulling round at the load. Then several hardened steel washers were introduced to lessen the friction, followed by conical roller races. Many such rollers have been fitted and are doubtless best for the heaviest loads. At first these rollers and their top and bottom races were turned in cast steel, but were not hardened.

More recently the ball-bearing makers have produced hardened and ground rollers and races suitable for crane hooks. Owing to the imperfect methods at first adopted in making the earlier roller races, the latter were not entirely satisfactory, so ball races were introduced. These have been successfully developed and have now become the common everyday practice.

CHAPTER X

SPUR GEARS

Nowadays one should design toothed gearing with more regard to *durability* than mere strength, in accordance with the recommendations, formulæ, tables and graphs contained in B.S.S. No. 436 (1932) for machine-cut gears, including both helical and straight spur wheels.

In standard gears the full depth tooth of the involute form, with a pressure angle of 20°, is adopted; although one recognizes that short or stub-tooth gears, with a pressure angle of $14\frac{1}{2}°$, have been used successfully for many years.

The materials which may be used in the manufacture of British standard gears are cast iron, malleable cast iron, forged steel, nickel steel, and nickel-chrome steels. To promote quiet running, high-speed pinions may sometimes be made of rawhide, compressed paper, fabroil or phosphor-bronze. In fixing sizes one has to take into account a surface-strength factor, whose value varies greatly with the nature of the material composing the wheels.

Moreover one has to consider the nature of the load in respect of steadiness or variability, intermittent action and the probability of overloads. Shocks are difficult to allow for. On variable load double-helical cut gears are apt to run more quietly than plain spurs.

Peripheral speed is now regarded as less important than revolutional speed, so that the high revolution pinion is the determining factor in fixing the pitch. The tooth load must go down as the revolutions go up.

Many years ago it was held by Reuleaux that, in order to ensure proper durability, the wheels of a train of gearing should be made the same width of face, though of varying pitch, throughout the whole series; although this uniform width certainly has been contrary to the usually accepted practice of British engineers.

Horse-power calculations are now made separately for the pinion and for the wheel, first of all as regards *wear* only and secondly for *strength* only. Then the least of the four resulting figures is taken as the capacity of the *pair.* This process is a rather lengthy one.

In 1916 Daniel Adamson read a paper on " Spur Gearing " before the Institution of Mechanical Engineers, and he put forward the convenient guiding rule that the product of the wheel revolutions per minute by the pressure in pounds per inch of width of wheel face must not exceed 174,000.

In the case of cranes for foundries and steelworks it is best to *enclose* in substantial gear cases the whole of the gearing, with the exception of the hoisting drum-wheel and pinion, also the last wheel and pinion in each of the horizontal motion drives. Then the durability of the gears is superior to that on machine-shop cranes with *open* gearing. Yet the accessibility of all parts for inspection and overhauling is an important consideration.

Cast Gears.—Formerly spur wheels were either machine-moulded from wood segment blocks or else moulded from complete iron patterns, which had been made either on a moulding machine or cut on a wheel-cutting machine. The teeth were of *cycloidal* form, set out by the aid of Willis's odontograph, a brass scale which gave radii and centres for wheels of all sizes, arcs of circles being thus used as sufficiently close approximations to the true epicycloidal and hypocycloidal shapes.

The smallest pinions had 12 teeth, having radial flanks. Larger wheels had teeth with spreading flanks, the thickness at the root of a tooth increasing with the number of teeth, so that at 80 teeth or so the shape of maximum strength was reached. In the Victorian period engineers used cut gears with *involute* teeth only for light high-speed gears, whereas now they are almost universal.

On the subject of cast gears generally the views held by Joseph Horner early in this century are worth quoting, for they are not without interest even to-day, coming as they do from an undoubted authority on pattern-shop and foundry practice.

If complete wood patterns are used for wheels, the teeth of the patterns should be machine cut, whilst they should be checked over from time to time and kept in good condition. But even then wooden patterns do not give such good results as wheel moulding machines.

True, *some* machine-moulded wheels are no better than wheels moulded from full wood patterns. This is so when badly worn tooth blocks are kept in use, or when the machine is worn, or when the moulding is done by a careless or an incompetent man. These three matters, viz., good blocks, an accurate wheel-moulding machine and a competent careful moulder are all essential to the production of accurate cast gears. Given these conditions, machine-moulded gears are nearly as good for slow and moderate speeds as wheels whose teeth are cut on wheel-cutting machines.

But such machine-moulded gears cost more than wheels cast from full patterns, because only one or two tooth spaces are moulded at once. Hence wheels cast from full iron patterns have been much used, being fairly accurate, if the teeth in the pattern had been cut on a wheel-cutting machine. They are clearly not quite equal to machine-moulded wheels, because a little taper has to be filed in the teeth to ensure their withdrawal from the sand, also frequently some slight breaking down occurs in the mould, which has to be made good (unless the pattern is drawn through a stripping plate), thus impairing the perfect form of the tooth. Still, as these *iron* patterns never wear out or become distorted, they are not open to the same objections as are *wood* patterns. The ring only of such a wheel pattern need be made of iron, the arms and boss being made of wood to fit within the rim.

The Lewis Formula.—For many years before the advent of British standard gears the strength of wheel teeth was commonly calculated by the so-called Lewis formula. This was introduced by Wilfred Lewis, who seems to have been the first engineer to take into account the form of the tooth when devising a working strength formula and tables. In Lewis's paper of 1893, read before the Engineer's Club at Philadelphia, he assumes that the whole load is taken at the extreme end of *one* tooth and determines the point of weakest cross section for teeth of various forms, putting forward the general formula

$$W = S \times P \times F \times Y$$

where W (lb.) is the working load,
S (lb. per sq. in.) is the safe working stress in material,
P (in.) is the circular pitch of teeth,
F (in.) is the width of face,
Y is a factor varying with the shape of the tooth and the number of teeth.

Values of Y for involute teeth and a pressure angle of 20° are given in the following table :—

No. of Teeth	Factor Y	No. of Teeth	Factor Y
12	0·078	30	0·114
14	0·088	38	0·122
16	0·094	50	0·130
18	0·098	60	0·134
20	0·102	75	0·138
25	0·108	100	0·142

The first part of the following table gives the safe working stresses on the material, in pounds per square inch, at various peripheral speeds, as laid down by Lewis for use in his formula. The second part gives the considerably lower stresses recommended by Barson for the teeth of crane-hoisting gears.

Speed in ft. per min.		100	200	300	600
Lewis .	Cast iron .	8,000	6,000	4,800	4,000
	Steel .	20,000	15,000	12,000	10,000
Barson .	Cast iron .	4,350	4,130	3,830	3,000
	Cast steel .	8,700	8,260	7,650	6,000
	Mild steel .	10,870	10,300	9,560	7,500

In order to illustrate the use of his tables and formula Lewis gave the following example : Let it be required to find the working strength of a 12-tooth pinion of 1-in. pitch and 2½-in. face, driving a wheel of 60 teeth at 100 ft. per min. (or less), the teeth being of the 20° involute form.

From the tables S here is 8000 lb. per sq. in. for a *cast-iron* pinion, running at a slow speed, and Y is 0·078, hence

$$\begin{aligned} W &= S \times P \times F \times Y \\ &= 8000 \times 1 \times 2{\cdot}5 \times 0{\cdot}078 = 1560 \text{ lb.} \end{aligned}$$

For the cast-iron wheel of 60 teeth, however, the result is very different, for here we see from the table of strength factors that Y is increased to 0·134, due to the stronger form of tooth, hence

$$W = 8000 \times 1 \times 2{\cdot}5 \times 0{\cdot}134 = 2680 \text{ lb.}$$

The weaker cast-iron *pinion* must therefore be taken as the measure of the strength of the pair.

If a *steel* pinion be substituted, however, the *wheel* will become the weaker member of the pair. In that case the horse-power that can be safely transmitted at 100 ft. per min. will be

$$\begin{aligned} \text{H.P.} &= \frac{\text{Safe load} \times \text{speed}}{33000} \\ &= \frac{2680 \times 100}{33000} = 8{\cdot}1. \end{aligned}$$

Since the peripheral speed equals the circumference of the pitch circle in *feet* multiplied by the revolutions per minute, we have

$$\text{H.P.} = \frac{W \times \pi D \times R}{33000}.$$

But if the diameter d of the pitch circle be expressed in *inches* instead of feet, we get

$$\text{H.P.} = \frac{W \times \pi d \times R}{12 \times 33000} = \frac{WdR}{126000},$$

which is in a convenient form for slide-rule calculation, giving the horse-power that may be safely transmitted by a pair of spur gears.

Now the question naturally arises, if we ran the above pair of wheels at six times the speed would they safely transmit six times the power ? The answer is superficially yes, but actually certainly not ; for in designing wheels *durability* has to be considered as well as strength. From Lewis's tables we see that the safe working stress at 600 ft. per min. would come down to 4000 lb. per sq. in., instead of 8000 lb. per sq. in. at 100 ft. per min.; and so we should get

$$W = S \times P \times F \times Y$$

$$= 4000 \times 1 \times 2{\cdot}5 \times 0{\cdot}134 = 1340 \text{ lb.}$$

Then $$\text{H.P.} = \frac{\text{Safe load} \times \text{speed}}{33000}$$

$$= \frac{1340 \times 600}{33000} = 24{\cdot}4,$$

whereas the horse-power would come out at $6 \times 8{\cdot}1$ or $48{\cdot}6$ if we merely took the safe power transmissive capacity as being directly proportional to the speed, regardless of any other consideration. The effect of inaccuracy in tooth forms is much more serious at high speeds than at slow speeds, for which reason machine-cut teeth are essential in the case of high-speed gears.

Another point has to be borne in mind where the resistance to motion is very variable, as in punching and shearing machines for instance, viz., the gearing must be designed with reference to the *maximum* load that can come on the teeth at any moment, and not be based simply on the *average* horse-power that has to be transmitted.

On the other hand the lengthy British standard formulæ given on page 122 for horse-power are intended to apply to gears used for industrial purposes which are running more or less *continuously*. When gearing is subjected to only occasional or intermittent use, as in most cranes, it is feasible to allow higher stresses, the *wear* being much reduced.

Comparison of Formulæ.—For comparison with the Lewis formula it will be instructive to determine the result given by the application of the British standard horse-power rules to the identical pair of spur wheels considered above. The rather long process demands the use of the tables and graphs given in B.S.S. No. 436 (1932).

Let Z = zone factor (see Chart No. 8).
X = speed factor (see Chart No. 11).
N = speed in revolutions per minute.
F = face width in inches.
S_c = basic surface stress factor.
T = number of teeth in wheel or pinion.

$P=$ diametral pitch of teeth.
$S_b=$ basic bending stress factor.
$Y=$ strength factor (see Chart No. 10).
$K=$ pitch factor (see Chart No. 12).

Then the horse-power for *wear* is

$$\frac{S_c \times X \times Z \times F \times N \times T}{K \times P \times 126000}.$$

In the case of the cast-iron *wheel* in question, this becomes

$$\frac{1100 \times 0{\cdot}41 \times 1{\cdot}3 \times 2{\cdot}5 \times 120 \times 60}{2{\cdot}5 \times 3{\cdot}14 \times 126000}=10{\cdot}6$$

as the horse-power capacity of the wheel as regards *wear*.

Also the horse-power for *strength* is

$$\frac{S_b \times X \times Y \times F \times N \times T}{P^2 \times 126000}$$

which, for the *wheel* in question, becomes

$$\frac{6000 \times 0{\cdot}41 \times 0{\cdot}6 \times 2{\cdot}5 \times 120 \times 60}{3{\cdot}14^2=126000}=21{\cdot}3$$

as the horse-power capacity of the wheel as regards *strength*.

Now we come to the *pinion* of 12 teeth. Assuming this to be made of 0·4 carbon steel, normalized, the surface stress factor S_c is 1400. Substituting the various values in the above *wear* formula, we get

$$\frac{1400 \times 0{\cdot}3 \times 1{\cdot}3 \times 2{\cdot}5 \times 600 \times 12}{2{\cdot}5 \times 3{\cdot}14 \times 126000}=9{\cdot}9$$

as the horse-power from the wearing point of view.

If the pinion were made of mild steel and case-hardened, the value of S_c would be increased to 9000 and the horse-power for *wear* to $\frac{9000}{1400}$ of 9·9, or 64.

Lastly, the *strength* horse-power of a pinion made of 0·4 carbon steel normalized is

$$\frac{22000 \times 0{\cdot}3 \times 0{\cdot}62 \times 2{\cdot}5 \times 600 \times 12}{3{\cdot}14^2 \times 126000}=59.$$

Thus the horse-power capacity of the pair may be taken as 10 as regards wear, and as 20 for strength.

CHAPTER XI

SLINGS, SKIPS, GRABS AND LIFTING MAGNETS

THE use of slings, grips or grapples of some kind is necessary when lifting goods in containers (such as bags and cases), also machinery parts and entire machines, for the purpose of connecting or slinging the load to the crane hook. When lifting goods in bulk (such as coal and coke), both skips or buckets and grabs are employed; though grabs are far more important labour-aiding appliances than skips when working on a big scale.

For lifting steel bars, joists and plates one commonly uses chain slings, though lifting magnets can often be utilized to advantage for this duty. For lifting scrap iron and pig iron, nothing is so convenient as cranes equipped with electro-magnets; at least when the operations are of sufficient magnitude to justify the expenditure.

A.—SLINGS

A sling is a length of rope or chain which is coiled around and secured to an object that has to be hoisted by a crane. A sling may be endless, or it may have eyes, rings or hooks at the ends. For moderate lifts, *rope* is often used in preference to chains, as being less liable to slip off the job and perhaps less likely to snap suddenly in the event of an overload. For handling packing cases special slings are used to grip the sides of the case. Timber is gripped by slings or dogs which bite into logs as they are hoisted.

In engineering workshops *chain* slings of various kinds hold the field. They are very reliable if properly looked after and frequently annealed. The chains should be of reasonable length, however, as very short slings are liable to be overstressed and to fail, when the inclination of the chain to the horizontal becomes too small. In large workshops on heavy work certain men known as ‘ slingers ’ have the duty of slinging jobs and of signalling instructions to the crane drivers.

Slinging.—Some common methods of slinging various objects have been grouped together in Fig. 82 and briefly described by Joseph Horner. The quickest device is to bend the sling around the work once and pass the free end through the bight or loop, carry it up and slip it over the hook, as at A. To ensure steadiness and even balance in long pieces the lower parts of the sling may be separated a little. Added security is gained by passing the free end around once more into a second bight, as at B.

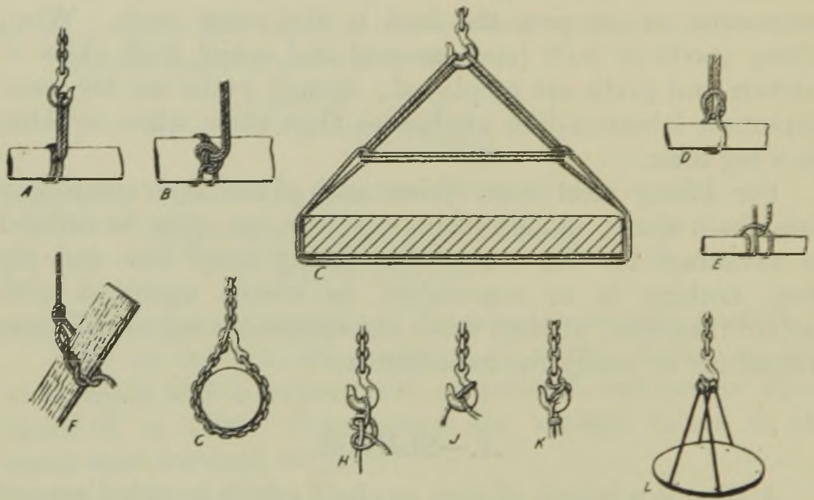


Fig. 82.—Methods of Slinging.

Such devices are suitable for pieces of work that are of small dimensions across. Length is immaterial, because a long piece can be steadied by a man at one end. But a *broad* article cannot be embraced by an ordinary sling. Two ropes have to be used ; one to embrace the work, the other to be passed through the ends and hitched on the crane hook, as at C.

A slip knot is used for slinging. An overhand knot is first formed, and the standing part of the rope is passed through the knot and pulled taut, as at D. This knot is often duplicated on a long piece of work, so keeping the latter horizontal.

A magnus hitch is used for slinging planks and poles on outdoor erection work. The rope is taken around the plank three times and passed through the last bight, as at E. A timber hitch that cannot slip is made by passing the rope around the timber and around the standing part, and back around itself several times, as at F.

Many a lift is made with a single-sling chain, hung by its eye from a crane hook, by simply bending it round the object and inserting the hook of the sling in one of the links, as at G.

When a timber hitch or a magnus hitch is made at one end of a single rope, the other end can be attached to the crane hook by a single or a double Blackwall hitch, J or K, or by a sailor's knot H. The last is the most readily made, and it cannot slip.

There is much work that cannot be safely slung in this way, either because it is too large, or because the sling would slip, or because a truly level lift is requisite. This is the case more especially in foundry, boiler shop and erecting shops. Large plates and rings are examples of such work.

A plate may be lifted *edgewise* by a common sling chain or rope without much risk of slipping, if only the lower bends of the sling are spread well out. But a plate cannot be lowered flatwise in this way. Hooks and chains with or without swivels are often used in such cases, as at L. When plates have rivet or bolt holes around their edges, the safest way is to use eye bolts or even common bolts. Hooks at the end of sling chains may be passed through the eyes of eye bolts, or the shutting-link of the sling chain may be made to encircle the body of the bolt, passed through it before the nut is put on. Or a bar may be passed through a hole, and a bar slung to the crane hook.

Chain slings are liable to damage the finished surfaces of machinery details unless special protectors are used. Slipping of the links also cause shocks and heavy stresses in the crane. Only the very best material should be used for all lifting slings, also the allowable loads should either be marked on them or posted where easily seen. Besides the usual hemp and wire ropes, special flat-rope slings of either hemp or steel wire are made, with suitable rings or thimbles in the ends.

B.—SKIPS OR BUCKETS

For carrying loose materials, builders and contractors make extensive use of skips, which are commonly made of steel plate of substantial thickness ; though formerly wood, reinforced with iron fittings, was sometimes employed. The simplest kind of skip is a conical bucket, suspended by a loop connected low down the sides, below the centre of gravity. To its rim is attached a forked dog, bail or trip, embracing the loop. When this dog is knocked upwards, the tipping bucket overturns and discharges its contents, which have been filled in by hand shovelling.

Another type—the drop-bottom skip—discharges without overturning, two doors being hinged at the bottom. On slacking off a chain passing up from them, these doors open downwards, thus allowing the contents of the skip to drop out freely.

Special skips have also been designed to open automatically when used in conjunction with cranes and transporters handling coal in quantities from barges and ships into coal stores and bunkers, though grab-buckets are now more commonly utilized for this purpose.

Other skips of special size and shape, mounted on wheels to form cars, are made for raising coal and ashes in power stations by means of skip-hoists, as described in Chapter XXIV.

In the foundries of Ley's Malleable Castings Co. Ltd., Derby, regular use is made of large rectangular shovel-like steel skips, each holding some 3½ tons of metal or hard scrap ; which are slung from overhead travellers when charging the 20-ton reverberatory furnaces, after temporary removal by the crane of a few of the firebrick-lined ' bungs ' forming the furnace roof.

A type of self-discharging skip with bottom doors or flaps is described in Zimmer's " Mechanical Handling of Material," on page 428. This skip, though filled by hand, discharges its load automatically, after the manner of a single-chain grab.

C.—GRABBING BUCKETS OR GRABS

Before the advent of mechanical grabs, plain buckets or skips were much used for transporting loose materials. But they involved too much labour and were not so speedy in operation. The modern grab, on the other hand, is a wonderful labour-aiding device, of great utility both for lifting bulk materials and for excavating. Special machines have been designed, however, solely for excavating and trenching. Such ' excavators ' are still more rapid in operation than grabs handled by ordinary cranes, which they tend to displace. Yet for unloading purposes grabs are more used than ever, being conveniently and efficiently manipulated by cranes, transporters and telphers.

The useful effect or efficiency of a grab depends partly on the shape of the jaws and partly on the nature of the material handled. The greater the angle of repose of the latter the more difficult it is to gather the material into the grab. The jaws of any grab will deal with a light material of uniform size much more readily than with a heavy material containing big pieces. Thus a grab will fill to its full capacity sooner with grain or sand or small coal than it will with lumpy coal or iron ore.

Much time and expense are undoubtedly saved by utilizing grabs to the fullest extent for picking up materials like coal and iron ore in bulk. They are commonly made to operate by either a single rope or a double rope. A single-rope grab can be fitted to any crane lifting on one fall of rope. On the other hand a double-rope grab needs an extra drum on the crane, in order to coil up the opening and closing rope of the grab. This drum should be driven through a *friction* drive by preference, though a *spring* drum is satisfactory if the lift of the hook is only small.

For operating big grabs, occasionally two independent motor-driven winches are fitted, one for each rope. Then the opening and closing of the grab is done simply by moving the handle of the motor controller. Heavy grabs should have two *hoisting* ropes also, whether built on the single-rope or the double-rope principle. The greatest resistance to the movement of the jaws is towards the end of the closing motion ; hence the utility of toggle levers.

Grabbing work is very severe on a crane, whose nominal size should be some 50 per cent. greater than the combined weight of the grab and its load. To reduce the power consumption, an empty grab may be balanced by sliding counterweights.

The tendency of double-rope grabs to *spin*, and thus twist the ropes around each other, may be overcome by fitting a large sheave at the grab head, then leading the operating rope back to the jib head. Thus the grab is suspended on three ropes, spread apart by sheaves, which keeps it steady.

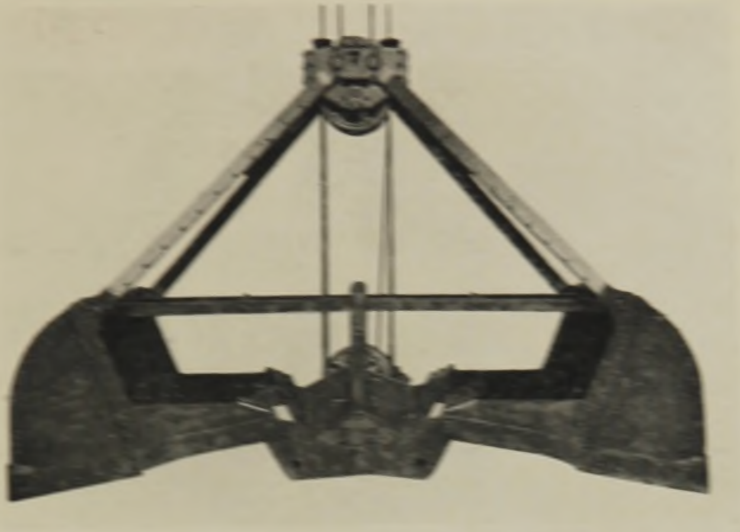
A self-dumping single-rope grab opens automatically when the hoisting rope is relieved from its weight. Such a grab needs only a single-drum winch for its operation, and it gives a higher duty than a single-rope grab having a *fixed* discharge gear.

A grab weighs considerably more than its load, as will be seen from the following table of weights and capacities. Thus a grab of 45 cub. ft. capacity, weighing about 30 cwt., will hold only 15 cwt. of coal. A more substantial grab of 42 cub. ft. capacity, weighing 3 tons, will hold about 2 tons of iron ore.

For Coal			For Iron Ore		
Capacity	Weight of Grab	Weight of Coal	Capacity	Weight of Grab	Weight of Ore
Cub. ft.	Cwt.	Cwt.	Cub. ft.	Cwt.	Cwt.
45	30	15	21	38	20
56	36	20	31	49	30
63	42	25	42	60	40
82	48	30	65	90	60
112	68	40	150	220	200

It is quite wrong to suppose or to imply that only one particular type of grab is made by each firm of manufacturers, thus enabling the different types of grabs to be designated simply by the names of their makers. As a matter of fact an experienced firm like Priestman Bros. Ltd., of Hull, regularly makes *many* types of grabs, some of which are described in the following pages, classified according to their special features and applications. They are all ‘ Priestman ’ grabs.

Modern grabs may be divided roughly into three classes, according to their method of suspension and their functioning. These are: (1) Ring-discharge grabs ; (2) Dumping grabs ; and (3) Double or Multi-line grabs. Two of these classes are suitable for operating by single-drum winches on cranes,



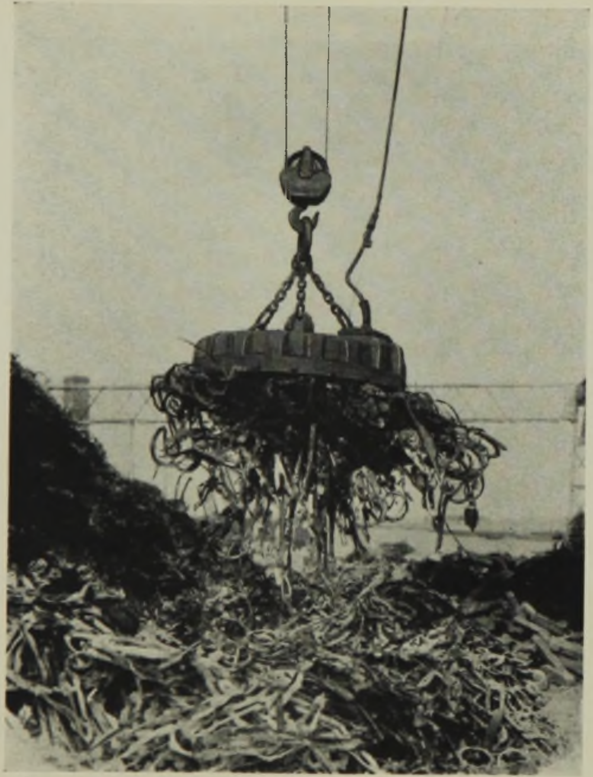
Priestman Bros. Ltd.

A.—BARNARD SCRAPER GRAB.

Priestman Bros. Ltd.

B.—GRAB LIFTING COAL FROM SHIP'S HOLD.

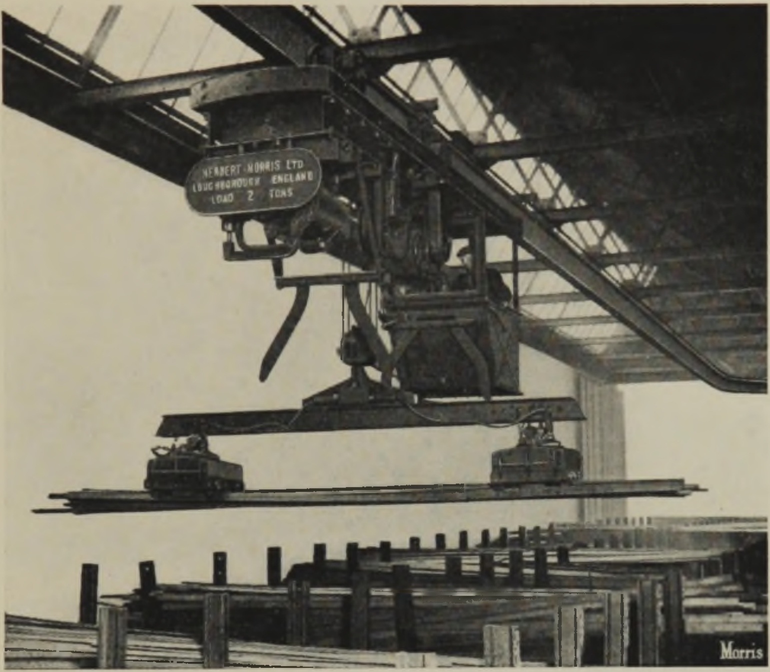
[*To face page* 128.



MAGNET LIFTING LIGHT SCRAP.

MAGNET LIFTING PIG IRON.

The Rapid Magnetting Machine Co. Ltd., Birmingham.



TWIN MAGNETS ON TELPHER LIFTING PLATES.

OVAL MAGNET SLUNG FROM TROLLEY.

Babcock & Wilcox Ltd., Renfrew.

A.—2-TON MAGNET CRANE FOR STEEL INGOTS.

Babcock & Wilcox Ltd.

B.—$2\frac{1}{2}$-TON CRANE WITH GRAB IN A FOUNDRY YARD.

transporters and telphers, whereas the multiple-line grabs need two drums to control their various motions.

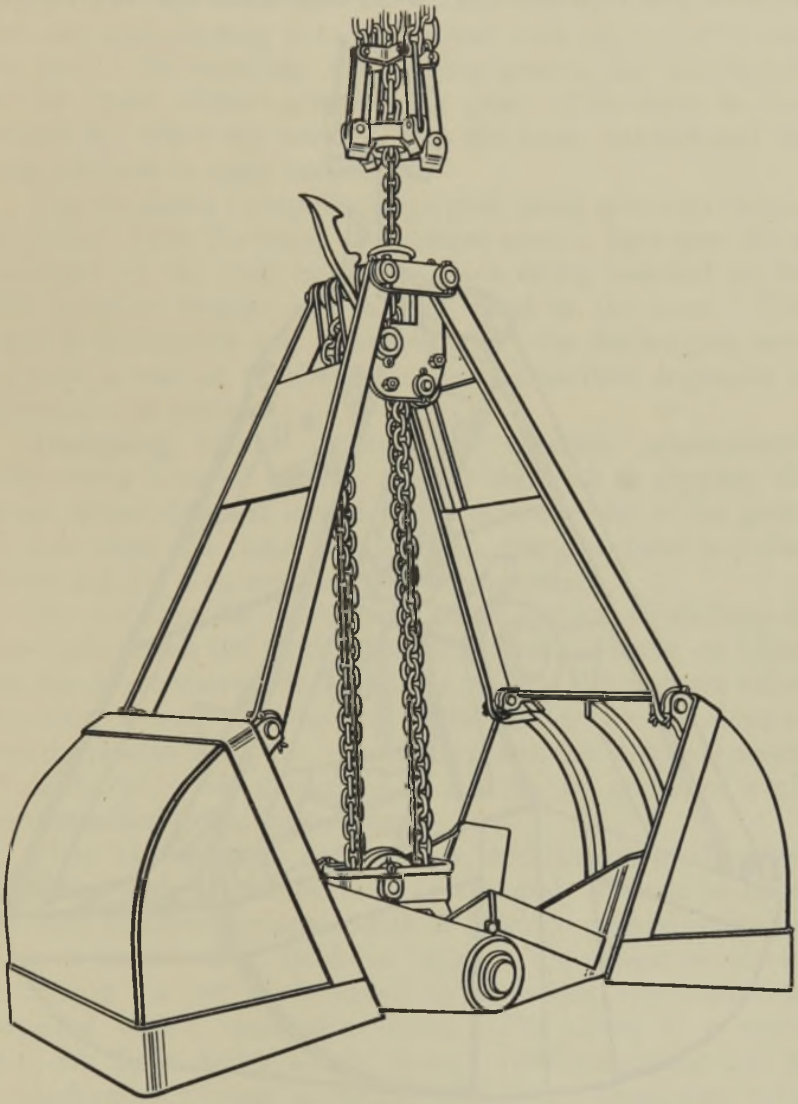


FIG. 83.—Ring-discharge Chain Grab.

Ring-discharge Grabs.—Grabs of the type shown in Fig. 83 are designed to empty their contents at a certain fixed height, by means of a ring or other device suspended from a crane or other lifting gear. Although this particular grab has a *single* holding hook only, engaging with the ring, no difference in principle arises when *twin* hooks are fitted, one on each side of the chain. In operation the closed grab with its load is hoisted up until the hook, projecting from the head, engages with the ring or cage shown.

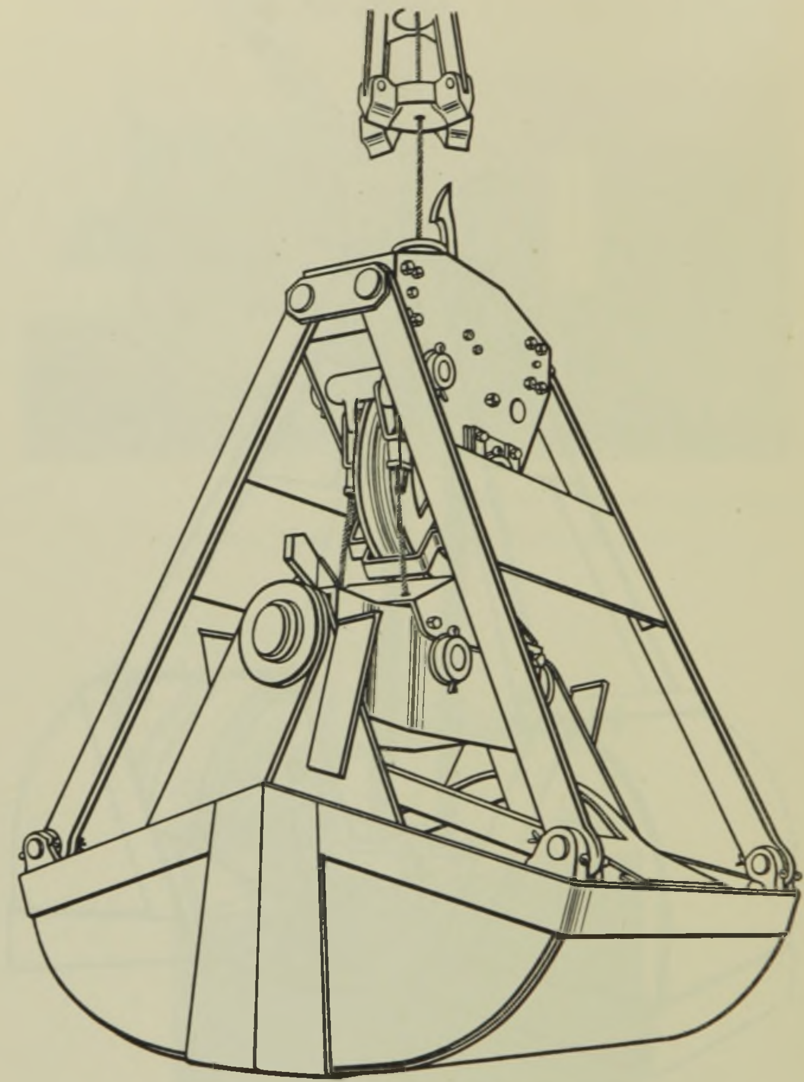


FIG. 84.—Ring-discharge Rope Grab.

On paying-out the hoisting chain the head of the grab is held by the hook, when the jaws proceed to open until a stop or *button*, fitted to the chain, passes into the grab head and engages with a locking mechanism. Then the grab is lifted slightly and the hook falls back, thus freeing the grab from the ring and allowing it to be lowered with open jaws to take its load. On reaching the digging points, the slacking-off of the chain releases the locking gear. The chain is then wound up, when the jaws close on the loose material and the now full grab is again hoisted up.

Fig. 84 shows a ring-discharge grab using wire *rope* instead of chain. Here the crane rope passes on to a light steel drum mounted in the grab head, the drum being notched on the rim so as to engage with a pawl fixed in the head. This pawl both controls and is controlled by the discharging hook in such a way as to allow the above-described sequence of operations to proceed.

Dumping Grabs empty their contents automatically after being lowered to rest. While the grab is digging, the lower sheave-block is locked to the centre girder of the grab ; so that when the chain is wound up, the grab head is pulled down and the jaws are closed on the material.

On reaching the discharging point, the act of slacking-off the chain causes the locking gear to release. Hence, on lifting up, the lower sheave-block and the head of the grab are raised together, thereby leaving the centre girder free to descend and the jaws to fall open. Dumping grabs may also be arranged to discharge, while suspended in mid air, by means of a trip cord attached to the locking gear.

Plate 14 depicts in two views a modification of the usual dumping grab where the head of the grab is made to open, in order to allow the crane hook or block to pass down inside. This is known as a ' hook-on ' grab. The chain withdrawn in closing the jaw is shortened so as to keep the head-room required within reasonable limits. The result is a useful grab for light duties which, though fully automatic, can be hooked on to a crane as readily as a skip. These two views were taken in the yard of the makers of the grab.

Double-line and Multi-line Grabs are those for which separate ropes or chains are used for hoisting and discharging. The hoist ropes pass around the purchase gear within the grab and the discharge ropes are usually attached to the grab head. A double-line grab, as shown in Fig. 85, is controlled by a single hoisting line and a single opening line. Such a grab can be discharged at any height by applying a brake to the discharging drum of the crane and allowing the hoisting drum to pay out. Possessing this advantage and being of simple construction, this type of grab is recommended for important grabbing jobs.

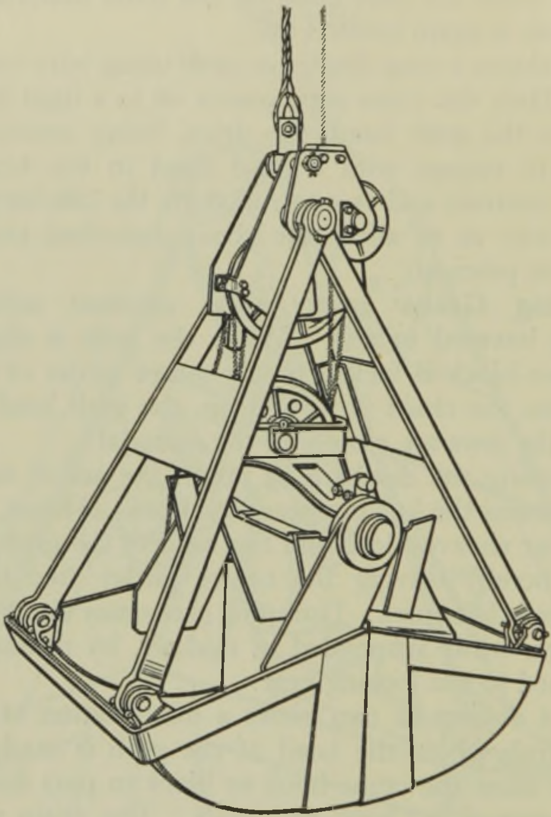


Fig. 85.—Double-line Grab, closed.

In multi-line grabs either the hoisting or the discharging line is duplicated, in which case we get the useful three-line grab. If *both* lines are duplicated we get a four-line grab. Although *ropes* are generally preferred, either ropes or chains may be employed at pleasure with this type of grab.

According to the duty required, any of the above-described grabs may be constructed with light plate jaws for handling such materials as coal, or with jaws of medium strength for lifting sand and crushed granite, or with heavy jaws for such severe duty as ore handling and dredging work.

The jaws of grabs for handling *grain* are made deeper than usual and the digging edges overlap one another, so as to prevent spilling of the grain. When handling very fine materials like powdered phosphates, *rubber* is inserted at the lip plates, thereby ensuring a perfectly tight joint when the grab is closed.

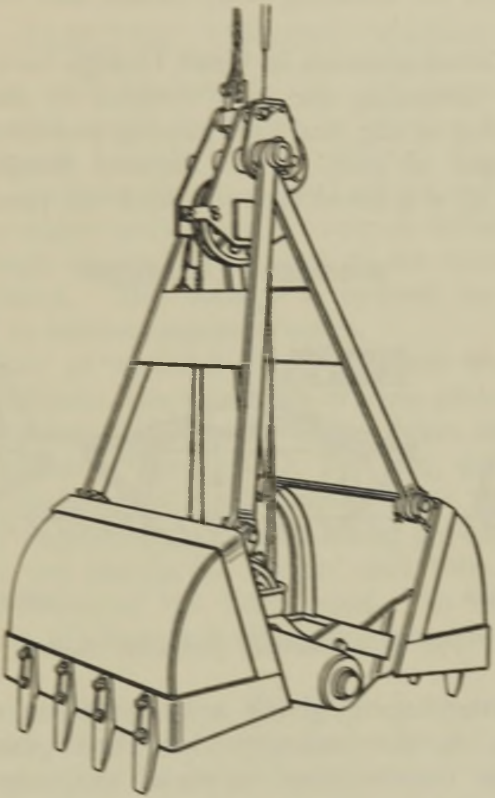
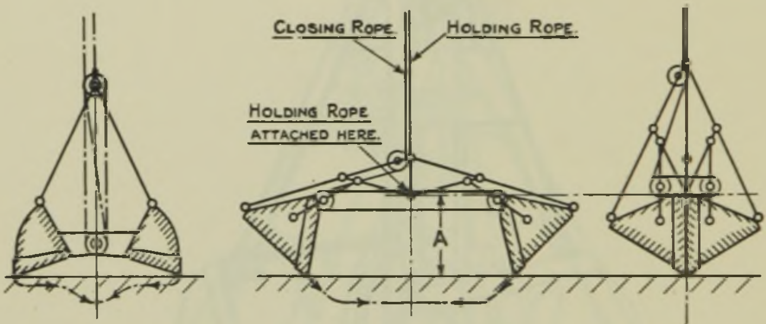


FIG. 85A.—Double-line Grab, open.

For application to overhead travellers and telphers preference is given to multi-line grabs and also to ring-discharge and dumping grabs having hoisting ropes or chains in *duplicate*, because this method of suspension maintains even loading on the drum bearings during the hoisting and lowering operations. Multi-line grabs are also not so liable to spin as are single-line grabs.

All the foregoing grabs have jaws of the ‘ clam-shell ’ type ; but there are other noteworthy forms, such as the ‘ whole-tine ’ grab pictured on Plate 14, which is used for excavating *clay*. Again, the four-bladed circular or ‘ orange-peel ’ grab, as originally designed for sinking cylinders, has now been developed into the ‘ multi-blade ’ grab ; a type that is utilized for handling scrap metals and various lumpy materials.

Recent Developments in Grab Design have been in the direction of increasing the *area* covered by the grab jaws when beginning to dig, and thus gaining greater efficiency for a given weight of grab. The ‘ Barnard Scraper,’ pictured on Plate 15 (A), is a novel type in which the jaws are pushed *outwards* as they open, giving a spread some 40 per cent. greater than in the ordinary clam-shell grab. In some materials this improvement increases the output by fully 25 per cent.



CLAM-SHELL GRAB ‘ LEVEL-CUT ’-GRAB

Fig. 86.—Priestman ‘ Level-cut ’ Grab.

An alternative method of gaining a big *spread* of the jaws is to design the grab to open right from the *head*, the opening-arms being placed inside the grab framework. Plate 15 (B) depicts a grab of this type, as made for discharging coal and ores from the holds of ships. The big spread of the jaws of such a grab saves a good deal of hand trimming and is better for cleaning up.

A drawback to this grab, however, is the fact that the widely spread jaws have more of a *scraping* action in taking its load than a digging action, which impairs its efficiency.

In an improved design, known as the Priestman 'level-cut' grab, this drawback is overcome. As shown in Fig. 86, the jaws are here *hinged* to the outer ends of the main arms. Then the pull of the closing ropes causes the jaws to turn on their hinges and move with a true shovelling motion into the material, thus greatly increasing the efficiency of the grab.

D.—ELECTRIC LIFTING MAGNETS

As early as 1820 Michael Faraday discovered that a very powerful magnet could be made by passing a current of electricity through a spiral coil of insulated wire enclosing a bar of iron. Such an electro-magnet enjoys the convenience of acting as a magnet only whilst the current actually continues to flow through the coil and ceases to act immediately the circuit is broken. This facility is utilized both in lifting magnets and in electro-magnetic brakes.

The pioneer of workable lifting magnets seems to have been S. T. Wellman, who used them to some extent in America for handling plates and slabs in 1895. Soon afterwards his design was improved upon by D. B. Clark, then serving as an electrical engineer with the Illinois Steel Co. The first commercially successful magnet for lifting pig-iron and scrap, however, was not put on the market until 1905, since which time the development has been rapid. An electro-magnet takes the place of slings, and often dispenses with the services of a slinger.

A magnet is hung from the crane hook and a flexible cable transmits the *direct* current to the magnet coils. After being lowered upon the iron or steel object to be lifted, it firmly seizes hold of its load by magnetic attraction as soon as the electric current is switched on by a switch placed in the operator's cabin. The magnet and its load are then safely hoisted up, moved to the discharge point and the load released by simply switching off the current.

Lifting magnets have developed along special lines according to the particular conditions under which they work, which probably entail more severe handling and rough usage than any other type of electrical plant suffers.

Shape of Magnets.—The original Wellman magnet was of oblong form, a shape still used for lifting plates and other flat objects. But for handling irregular pieces like rough pig iron, castings and scrap the circular form is more suitable. The magnet is hollowed underneath so as to retract the central pole-piece appreciably within the outer encircling pole. The periphery of the cast-steel casing is ribbed, in order to facilitate the radiation of heat from the windings.

Actually magnets are made square and oblong, round and oval, according to the requirements. The surface of magnet poles should be shaped to fit fairly closely to the shape of the objects usually lifted by them. If used for lifting iron pipes, for example, the pole-pieces should be hollowed out to fit them. Where *long* objects have to be lifted, several small magnets are suspended from frames or beams, so as to get a number of ‘ bites ’ or points of attachment.

Magnets are further suitable for lifting rails and plates, pipes and shafts, castings and forgings, also loose materials like rivets and bolts and machinery details. Long and flexible plates, however, need two or more magnets, hanging from a beam slung from the crane hook. Occasionally hooks or clips are used as a safeguard, after a plate has been picked up by a magnet, if it has to be carried over men, though the risk of a magnet failing to hold its load is really very small. Up to six steel plates at a time can be lifted, the precise number depending upon the thickness and weight of the plates and the type of magnet.

The Holding Capacity of a Magnet depends largely on the characteristics of the material to be lifted, including its magnetic conductivity or *permeability* and its temperature, also the shape and size of the pieces. It is important that the temperature should not exceed a black-heat.

For materials like sand-cast pigs and heavy scrap iron the holding capacity falls off, since such materials do not conform to the surface form of the magnet.

The magnetic effect produced in a magnet is directly proportional to the strength of the exciting current and to the number of turns in the coil. The magnetic force is greatest at a pole and falls off inversely as the square of the distance from the pole.

In order to attract the ‘ keeper ’ or ‘ armature ’ of a magnet with the maximum degree of force, the design must be such as to induce as many lines of magnetic force as possible to pass through the magnet and its keeper. Thus we may say that the strength of a lifting magnet is proportional to the sectional area of the iron core and of the keeper through which the lines of force pass. Moreover it varies directly as the number of ampere-turns in the exciting coil and inversely as the length of the wire in the circuit.

A magnet of 51 in. diameter, weighing 5400 lb. and consuming 27 amperes of current at 220 volts, equal to 8 electrical horse-power, will lift a so-called 'skull-cracker' ball weighing 20,000 lb., as used in some foundry yards. Yet the same magnet may pick up not more than 1500 lb. of iron from an irregular heap of pigs, and perhaps only 1000 lb. of light scrap iron. So the lifting capacity of a magnet varies a good deal with what has to be lifted.

For breaking up cast-iron scrap a magnet is clearly a valuable labour-aiding appliance; since the same magnet that lifts and drops the skull-cracker on to the casting to be demolished will also conveniently handle the metal itself, both before and after it is reduced to fragments.

The Weights of Magnets of different designs vary greatly, but according to 'Kempe' the following table gives the approximate weights of three sizes of lifting magnets, also the capacity or load, when lifting either solid steel ingots (A) or pig iron (B) :—

Magnet		Load		Power
Diameter	Weight	A	B	
In.	Cwt.	Tons	Cwt.	kW
36	16	7	9	3·5
42	25	10	14	5·0
54	39	18	23	7·5

The wide difference between the A and B values is remarkable. Taking the middle size, the 42-in. magnet will lift a solid steel ingot weighing 8 times its own weight, whereas the same magnet will lift little more than half its own weight of pig iron, with a power consumption of 5 kilowatts in each case.

In Fig. 87 is seen a form of magnet made by the Witton-Kramer Electric Tool and Hoist Co., of Birmingham, in which the pole-shoes are bolted to the casing. The coil is clamped into position in the shell by manganese steel clamps and asbestos packing-pieces, an air space being left between the shell and the coil. The shield protecting the coil is made either of non-magnetic manganese steel or of hard phosphor-bronze.

An electric crane equipped with a magnet requires an extra controller, for exciting the magnet when lowered on to the object to be lifted and for releasing it at the discharge point. Controllers for magnets are of the drum type ; non-inductive resistances being used to take up the induction of the coil when breaking circuit.

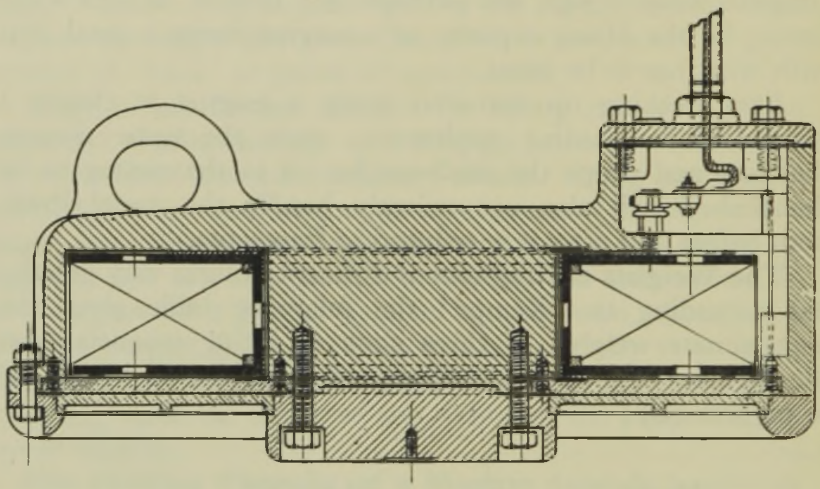


Fig. 87.—The Witton-Kramer Magnet. (From Zimmer.)

The Wiring needed for operating lifting magnets comprises a wire cable which is led over a system of pulleys provided with a counterweight to keep the cable taut. In the case of jib cranes this cable is connected to the supply in the crane cabin, but for travelling cranes it is usual to install two trolley wires alongside the bridge and to provide special collectors to pick up the current. A *spring drum* is sometimes fitted, upon which the cable is wound and unwound when the crane is in use.

A survey of the leading systems of control for lifting magnets is given in an article by W. A. Barson contained in the *Electrical Review* of February 1st, 1935, where the important influence of self-induction is fully considered. The three operations needed for magnet control are as follows :—

1. To supply the full exciting current for lifting the load.
2. To break the current for discharging the load.
3. To supply a small reversed current momentarily and not too soon, in order to complete the demagnetization by removal of the residual magnetism. With unsuitable control gear and careless operation there is danger of trouble arising from the high induced voltage due to the sudden collapsing of the magnetic field.

Objections to A.C. Magnets.—Although it is possible to make lifting magnets suitable for an alternating current supply, it is seldom done, for several good reasons. In the first place the *cost* of such equipment is very high, also the lifting capacity is inferior, and lastly the heating effect is troublesome. Hence the usual procedure, when only A.C. is available, is to use a motor-generator for converting alternating into continuous current to serve the magnet. An alternative, however, is to utilize a *rectifier* for producing a uni-directional current.

Applications.—Two instances may be given of the labour-saving features of lifting magnets, as cited in Kempe's "Engineer's Year Book." A 52-in. circular Phœnix magnet, weighing 50 cwt., has unloaded from trucks 600 tons of pig iron in rather under 7 hours, with the crane driver solely controlling the operations and no other labour being employed. Also a 62-in. circular magnet weighing 65 cwt. was fitted on a 12-ton electric overhead traveller serving a scrap storage ground. In 7 minutes it unloaded a truck load of steel turnings, a task that formerly occupied 4 men for 5 hours.

For lifting *hot* materials circular magnets are unsuitable, because the coils are too near the source of heat. Special magnets are made, however, where the pole-pieces are extended some 8 in. at the bottom, in order to keep the coils further away from the heat.

Plate 16 depicts a 46-in. magnet made by The Rapid Magneting Machine Co. Ltd., of Birmingham, in operation at the works of the Midland Motor Cylinder Co. Ltd., when lifting light scrap and also pig iron. The sizes of circular magnets made by this firm range from as small as 6 in. up to as large as 76 in. diameter.

As the lifting capacity of a magnet depends so much on the way that the material lifted is presented to the magnet and on the permeability of this load, no definite lifting power can be guaranteed. Yet under favourable conditions the following figures may be taken as average capacities of three selected sizes of magnets, together with their own weights and the current consumption of *cold* magnets at 220 volts. In the case of *hot* magnets, the current used is some 25 per cent. less.

Magnet		Lifting Capacity			Current
Diameter	Weight	Pig Iron	Heavy Scrap	Turnings	
In.	Lb.	Cwt.	Cwt.	Cwt.	Amps.
26	850	6	5	1·5	13
46	4150	15	12	8	35
66	8450	30	25	15	60

The oval pattern magnet depicted on Plate 17 is used for extracting ‘ tramp ’ iron, when suspended from a trolley over a conveyor. Due to the elongated effective magnetic field, a greater efficiency of extraction is secured by the oval magnet than by either circular or tri-polar magnets. An oval magnet can also be used effectively for handling steel plates and sheets, for which duty it is better than a round magnet of large diameter.

CHAPTER XII

TRAVELLING CRANE BEAMS AND END CARRIAGES

TRAVELLING cranes include all overhead travellers moving on elevated rail gantries, also Goliaths moving on ground rails. The term travellers is applied exclusively to these types, notwithstanding that portable and locomotive cranes with trucks also travel on rails, the distinction being purely conventional.

For workshop service no other type of crane equals the overhead traveller in general utility, while the Goliath crane is extremely useful for yard work, as it avoids the expense of an overhead gantry, thus causing less obstruction to cross traffic.

Timber Beams.—There is a good deal of variation in the frames of travelling cranes. The material employed for their construction is now always steel, though for many years timber was commonly used for crane girders, and some made of this material are still in service. Large balks of timber are not readily obtainable in a perfect condition of soundness, straightness of grain and freedom from knots. On the other hand, rolled steel joists are available of dimensions sufficiently large to eliminate any cost of building up, at least in the case of cranes of relatively small span and capacity.

Formerly timber was preferred, and may even yet best meet the requirements, in a few exceptional cases; as, for example, when a firm of builders purchase a set of ironwork and then proceed to construct their own timber framing. Or, again, when the cost of shipping steel girders abroad to some out-of-the-way spot is prohibitive, and only the machinery for the crab and travelling gears is shipped, the timber work being constructed on the site. This is perhaps the best procedure in countries like Tasmania, Vancouver and some other districts where large timbers grow. But it cannot be adopted in tropical countries, where ants and other insects commit great ravages in timber. Some other objections to wood are that it is subject to decay, and that timber beams have to be trussed with struts and tie-rods, whereas steel girders need no trussing as a rule.

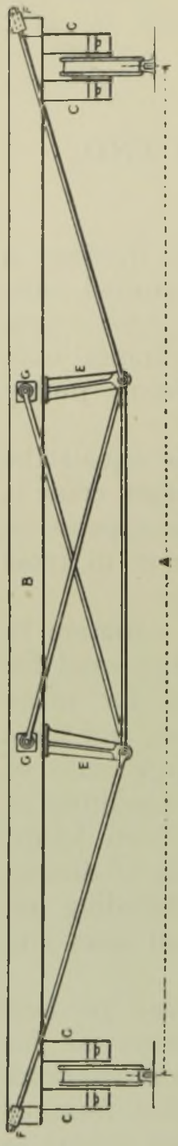


FIG. 88.—Trussed Bridge for Traveller.

Fig. 88 illustrates a timber trussed framework or bridge for an overhead traveller. In this old example both the main beams and the end-carriage beams are made of wood, though the latter were often made of cast iron. As an alternative, steel channels could be used throughout, and trussing could still be adopted in the case of longish spans, in order to utilize fairly light stock sections and to economize in head-room.

In designing crane bridges there are several matters of importance to be considered besides the load or lifting capacity. First of all there is the *span* A (Fig. 88) or distance between the centres of the running wheels, or tram wheels, or runners as they are variously styled. This is governed by the width of the crane gantry or shop runway, which depends on the width of the shop or of the bay to be served. Then there is the length of the *wheel-base* D, which must be sufficiently long to prevent the risk of cross-winding of the traveller on the runway rails. The length of the wheel-base in well-designed cranes is at least one-sixth of the span, whilst one-fifth is better. Many of the older travellers were faulty in this respect, resulting in broken wheel flanges, due to cross-working, combined with too much clearance between the flanges and the rails.

Looking at Fig. 89 we see that the two timber beams B, of square section, are carried on end beams C of timber, and the latter on flanged wheels. Commonly a vertically loaded beam should measure considerably more in depth than in width, and this rule is universal when steel girders are used. But in the case of timber it is more convenient to use *square* balks, sufficiently wide to ensure stiffness laterally and to provide for the necessary vertical strength by trussing, as in Fig. 88.

Cast-iron connections are usual for truss-rods. These comprise two struts E, by which the tie-rods are carried down to the proper depth, and anchorages F at the ends, which are fitted over the timbers and against which the tension of the screwed rods is adjusted by means of nuts. One possible variation is to use flat bars instead of round rods.

In a compound truss the counterbracing is not stressed when the beam is centrally loaded, so that one has to estimate the effect of the load when the counterbracing is fully loaded, this occurring when the load is directly over a strut. When a beam is loaded unsymmetrically the reactions of the supports are inversely proportional to their distance from the load. The actual stresses in the various members of a truss are best determined graphically, taking into account the weight of the beams as well as that of the crab and its load.

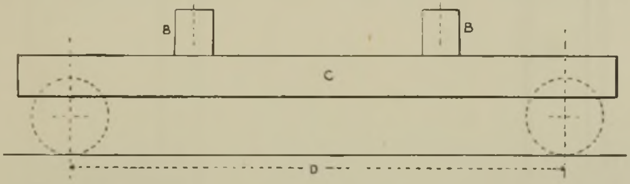


Fig. 89.—Timber End Carriage.

Calculation of Bending Moment.—Apart from the bending moment due to the dead weight of the girder itself, the maximum bending moment in ton-feet on a crane girder due to the loaded crab is given by the formula

$$\frac{W}{2S}\left(S-\frac{B}{2}\right)^2$$

where W tons is the equal load per wheel,
S ft. is the span of the girder,
B ft. is the wheel-base of the crab.

Thus in the case of an equal load of 10 tons on each crab-wheel, a girder span of 60 ft. and a crab wheel-base of 6 ft.,

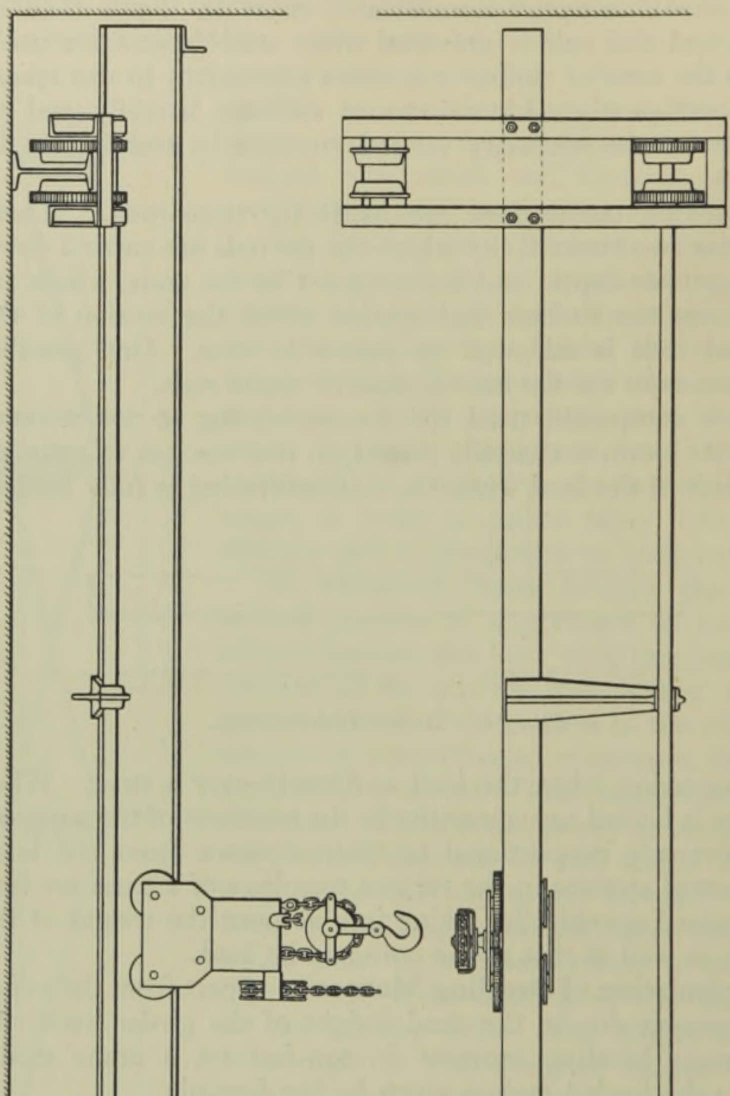


FIG. 90.—Simple Single-joist Hand Overhead Traveller.

Babcock & Wilcox Ltd.

60-TON ELECTRIC TRAVELLER AT A POWER STATION.

Babcock & Wilcox Ltd.

30-TON ELECTRIC TRAVELLER WITH DROPPED GIRDERS.

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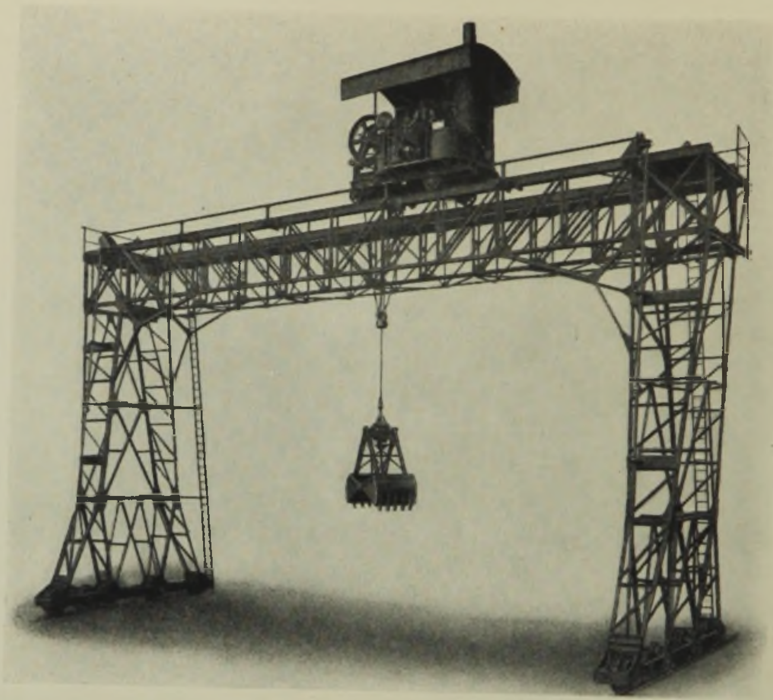
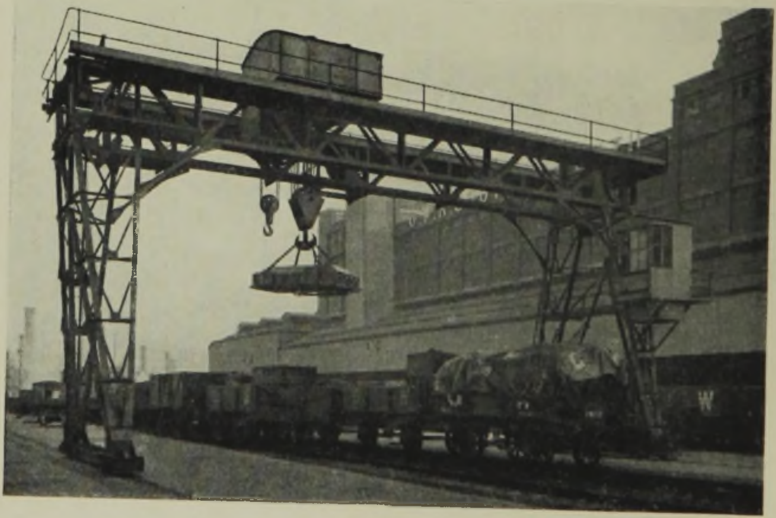


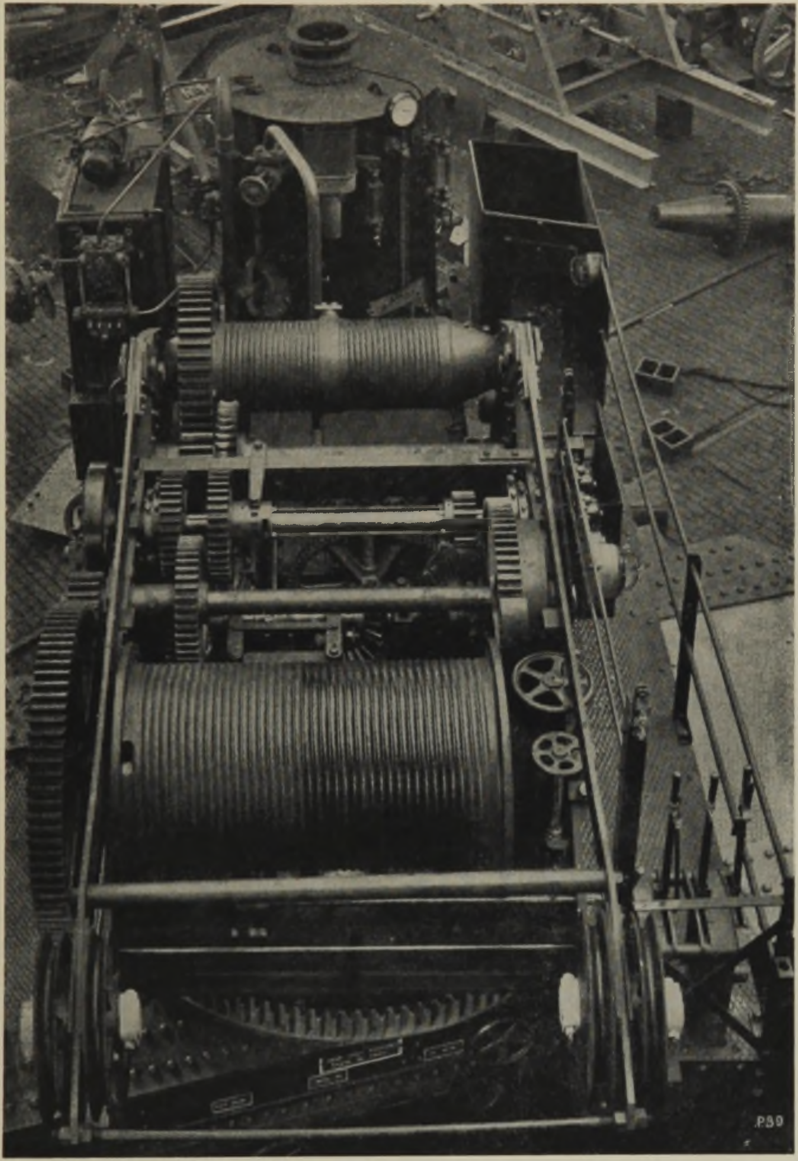
Stothert & Pitt Ltd., Bath.

STEAM GOLIATH CRANE WITH GRAB.



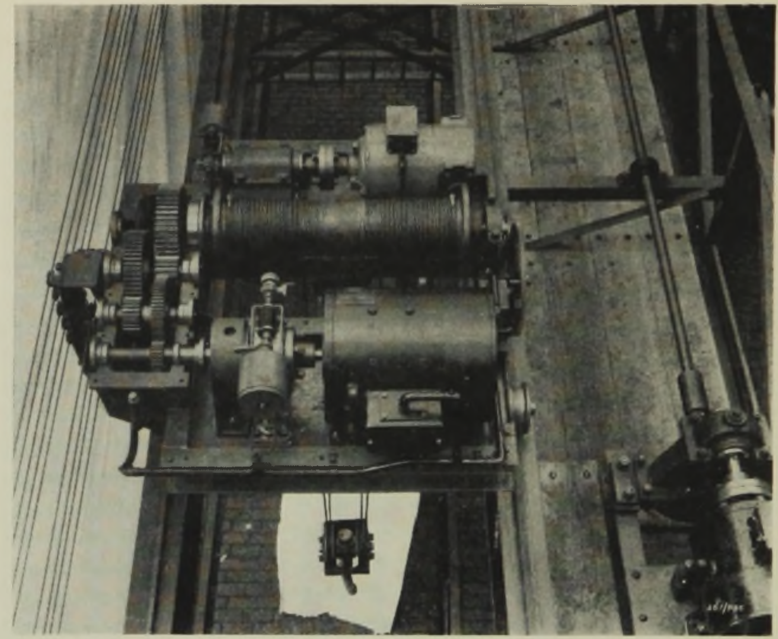
Babcock & Wilcox Ltd.

35-TON ELECTRIC GOLIATH CRANE.

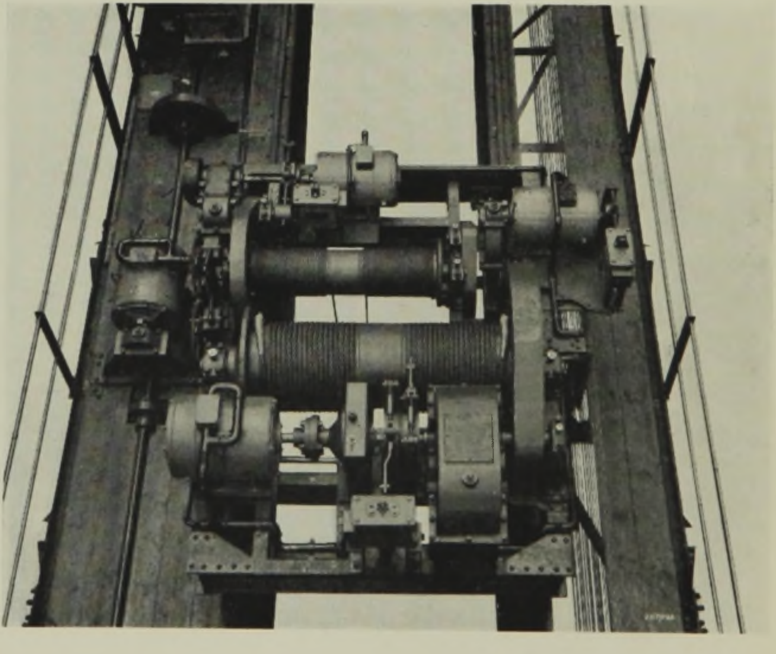


Joseph Booth & Bros. Ltd.

20-TON BRIDGE ERECTION CRANE. TOP VIEW OF MACHINERY IN FITTING SHOP.



LIGHT 2-MOTOR CRAB FOR TRAVELLER.



Joseph Booth & Bros. Ltd.

30-TON 3-MOTOR CRAB WITH 5-TON AUXILIARY HOIST.

To face page 145.]

the greatest bending moment on the girder due to the crab load becomes

$$\frac{10}{2 \times 60}\left(60-\frac{6}{2}\right)^2$$

which works out to 270 ton-ft. This figure compares with a moment of 10 tons × 30 ft. or 300 ton-ft. at the centre of a 60-ft. girder carrying there a concentrated load of 20 tons.

Steel Girders.—The employment of steel for traveller frames affords scope for much variety of design and a large extension of dimensions, capacities ranging from a ton to over 100 tons. Rolled-steel joists are used in the lighter class of cranes. They are extremely handy, because they are ready for immediate service without any expenditure for labour, except the drilling of bolt holes at the ends and the attachment of rails on the top.

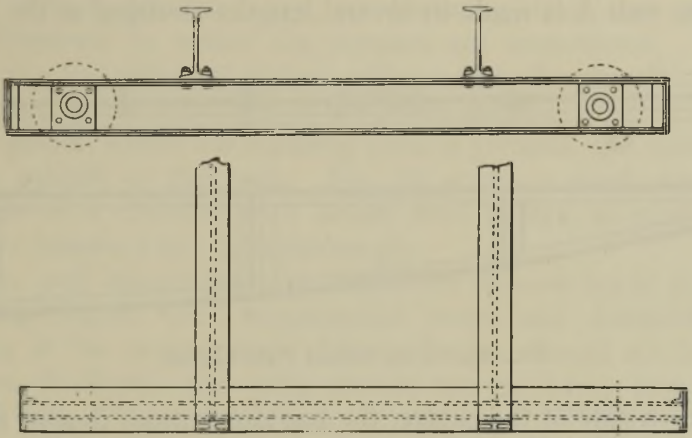


FIG. 91.—End Carriage for Light Crane.

The simplest type of beam is that shown in Fig. 90, where a single joist is supported on two end cradles or carriages carrying the travelling wheels. Such a crane carries no crab but only a trolley, whose wheels may run either on the top flange of the joist or on the bottom flange. The trolley carries pulley blocks of numerous types, either hand-operated or electric. The end carriages are now commonly built up of steel sections.

An advance on this is the arrangement of two parallel joists bolted to two end joists of lighter section (Fig. 91) carrying the travelling wheels. This design is only suitable for light cranes, because a parallel section is not the most economical of material and is therefore heavier than necessary for a given strength. A rolled joist becomes objectionable in long spans, where its comparatively small width gives inadequate resistance to the transverse loading arising from inertia when starting and stopping the longitudinal travelling motion of a high-speed crane. From this point of view the special broad flange beams are better than beams of the ordinary British standard section. Nearly all girders of great length are of variable depth, being either ' fish-bellied ' or triangulated. See 60-ton crane example depicted on Plate 19.

In the typical fish-bellied plate girder indicated in Fig. 92, the web A is made in several lengths abutting at the joint *a* on each side of the centre, the top and bottom flanges being jointed at *bb*. These joints are covered with broad plates riveted across the vertical joint *a* by the plates *c* and across the joints *b* with the cover plates *d*. The angles C are united with covering angles *e* at the joints D. An important point is that none of these joints should be made in the same locality, but always at different planes, thus ' breaking the joint,' as the expression goes. At intervals the vertical stiffeners are riveted on.

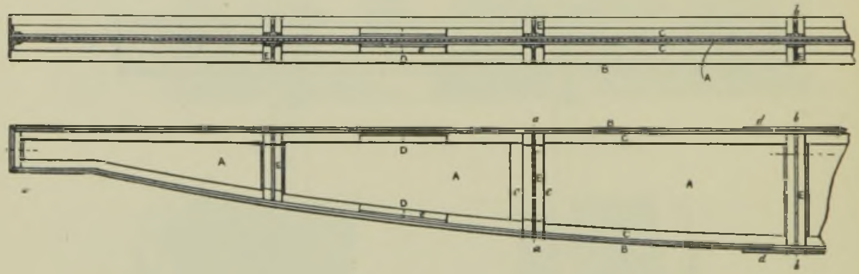


Fig. 92.—Fish-bellied Plate Girder.

Welded Girders.—Nowadays it is possible to construct plate girders, and even lattice girders, entirely without rivets by applying modern methods of welding, using either electricity as the source of heat or the oxyacetylene blowpipe flame. There is undoubtedly a saving in weight and in the labour of marking out and drilling rivet holes. Yet riveted girders are still far from being obsolete, despite the rapid advance of welding processes and practice. It depends largely on the workshop equipment and the particular experience of the workmen available as to which method of construction is the more rapid and economical. There is also the important question of safety or reliability to be considered. Some engineers would hesitate to say that welding is as completely reliable as sound riveting under all circumstances.

Weight Reduction.—A cambered beam is generally solid plated, and a solid plate is not the most economical form as regards weight. During recent years crane makers have followed bridge builders and have constructed beams of both parallel and cambered forms with lattice bracing, so saving metal over the plated design, by disposing struts and ties in the directions in which the stresses are transmitted. The result is a lightening of girders without loss of strength. The bars forming the vertical web are made thickest near the ends of the girder, where the shearing force is greatest, and thinnest at the middle of the span. Fig. 93 shows a good modern example of a traveller with lattice steel bridge, as made by Herbert Morris Ltd., Loughborough.

It is well known that the maximum stresses occur at the top and bottom of a symmetrical beam and diminish to nothing at the neutral axis. Hence flanges should not be of uniform thickness, and webs should not be heavy near the neutral axis. These conditions are roughly fulfilled by rolled joists, and they may be still more nearly realized by girders which are built up with webs and angles, or with angles and tees and bracing, because the metal can be massed where most needed and cut down elsewhere. The depth of a crane girder is usually made one-twelfth of the span.

This matter is less one of cost than of weight. It costs more money to build up girders than to use rolled joists, since the labour needed costs more than the value of the steel saved. The main point is the reduction in the dead weight of the crane. By lessening this the loads on the travelling wheels and axles are reduced and less power is required for operating; a point of much importance in the high-speed travellers which are now so common.

Rigidity.—In designing girders two other matters have to be settled, viz., rigidity depthwise, *i.e.*, as opposed to buckling or crumpling, and rigidity sideways, to resist the lateral

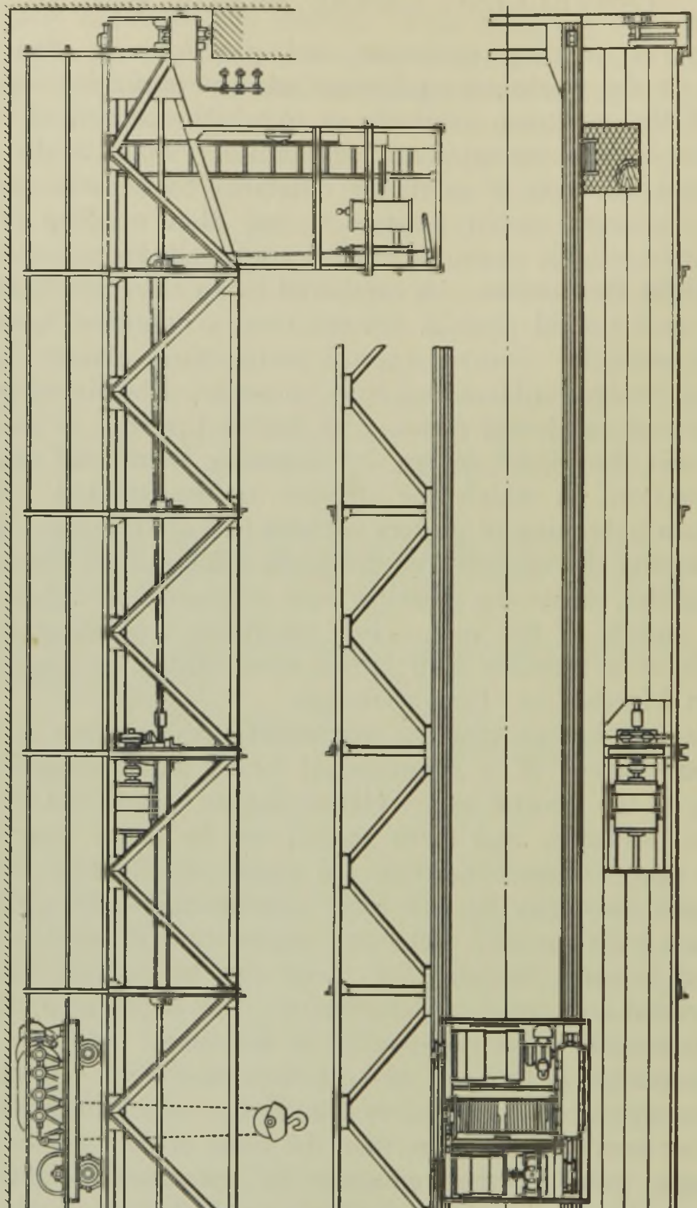


FIG. 93.—Modern Electric Overhead Traveller with Lattice Girders.

stresses produced by the rapid longitudinal travel of the crane, due to its inertia when starting and stopping.

Rigidity depthwise is imparted by vertical stiffeners usually of T section, which are riveted down the webs at intervals. Rigidity sideways is attained in two ways, the simplest way being to widen the top and bottom flanges of the girder. In heavy cranes, however, the required rigidity is secured by using box girders in which the two webs are placed a few inches apart and riveted to the top and bottom flanges.

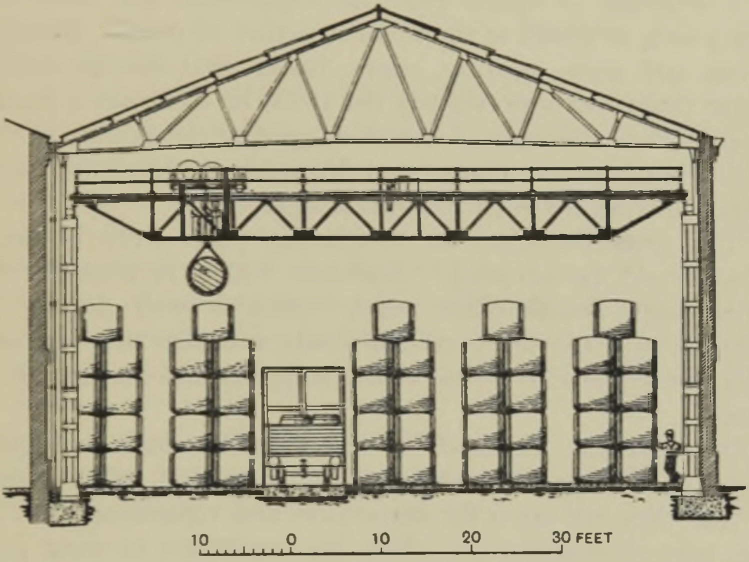


FIG. 94.—Traveller Stacking Hogsheads of Tobacco.

In the lattice type of girder a practice now much in vogue is to attach lateral bracings to the outside of the main girders, which also serve to carry platforms. The design combines great lateral rigidity with lightness and is very suitable for modern high-speed travellers.

Fig. 94 illustrates a modern application of a light overhead traveller with steel lattice girders to the handling of hogsheads of tobacco inside a warehouse belonging to the Port of London Authority. It will be noticed that the crane driver's cage, containing the controls, is placed immediately below the crab, where there is a clear view of the load suspended from the hook.

This illustration appears in an instructive paper by Asa Binns entitled " Recent Developments in the Mechanical Equipment of the Port of London Authority," which was read in 1932 before the Institution of Mechanical Engineers.

The Views Expressed by Daniel Adamson.—In the year 1925 a useful paper entitled " Notes on the Design and Construction of Electric Cranes " was read before the Manchester Association of Engineers by Daniel Adamson,[1] who became President of the Institution of Mechanical Engineers in 1929 and died in the following year. This paper gave evidence of much practical experience and dealt with such points of detail as the main structure of cranes, travelling wheels and axles, gearing, ropes, hooks, and electric motors. About thirty years previously (in 1896) he had read a pioneer paper, before the same Association, giving the results of tests of the first electric cranes put to work in England having electric motors for each individual motion.

The question arises as to whether plate webs or lattice webs should be adopted. Adamson rather favours the box girder, with double-plate webs, which is well devised for resisting both the usual *vertical* loads and also the *horizontal* loads that come into action at the stopping and starting of the crane.

In situations exposed to the weather and consequent corrosion of parts the undoubted advantages of lattice girders are that they are open for inspection and repainting, also the open type of construction offers less resistance to wind pressure. The virtue of lightness claimed for lattice girders is thought by Adamson to be often more apparent than real for two reasons. In the first place the upper flange must be made substantial enough to carry the wheel load of the crab between the points of support of the diagonal and auxiliary member connections. This condition involves heavier top flanges than would be necessary with plate webs. In the second place *lateral* stability and stiffness must be ensured by the addition of outrigger girders. This is objectionable, because

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[1] I knew and admired Daniel Adamson personally as a fine type of Lancashire engineer, who did some good work. He was Chairman of the Wire Ropes Research Committee. His father, Joseph Adamson, founded the firm of Joseph Adamson & Co., Hyde, as boilermakers, about 1874, and twenty years later he began to make electric travelling cranes. Joseph died in 1920.

the deflection of the main girder under full load is not accompanied by a corresponding deflection of the outrigger girder, and so the relation of the two is distorted.

In some designs of lattice girder lightness is attained at the risk of safety by ignoring good practice as regards the ratio of length of a strut to the least radius of gyration (K) of the section. For example, on some crane girders one may find struts made of $2 \times 2 \times \frac{1}{4}$ in. angles and 6 ft. long, giving a ratio (K) of 180 to 1, instead of the limit of 120 to 1 that is asked for in standard girder specifications. Actually no section less than $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ in. should be used for any diagonal strut 6 ft. long.

For double-plate web or *box* girders the following proportions of depth to span are suggested by Adamson : Depth in centre equal to one-sixteenth of span up to 20-ton cranes, one-fourteenth of span up to 60 tons and one-twelfth of span up to 100 tons. The depth of the ends is generally about four-sevenths of the depth at the centre.

The width of the flanges should be about two-fifths of the depth at the centre. The proportion of width to thickness must be such that there is no appreciable deflection in the flange plates between the two webs of the box girder. The proportions named will give girders having a *horizontal* strength to resist inertia loads equal to one-fifth of the vertical strength, though the top flanges take most of the horizontal load.

Cranes of over 30 tons capacity by 50 ft. span or of 50 tons capacity by 30 ft. span need *stiffeners* on the vertical webs towards the ends of the girders, where the shearing force is greatest. If these stiffeners are fitted internally then diaphragms connecting the two webs of box girders will afford all the stiffness required.

Girders for Long-span Cranes.—In the case of heavy cranes of very long span, say, 70 ft. and upwards, box-plate girders become unsuitable ; whereas single-web open lattice-braced girders, with the addition of outrigger lattice girders, are in general use, as they meet the requirements perfectly. They are commonly built with an initial camber of 1 in. per 100 ft. of span.

The longitudinal travelling gear is placed between the main girder and its outrigger, while the inspection platform or walk-way rests on the top horizontal members. Thus the outrigger takes no vertical load from the crab, and only part of the weight of the travelling gear in addition to the platform load.

The outrigger or auxiliary girder itself (Fig. 95) is usually a very light structure built with single-angle flanges and struts, and having flat-bar diagonal bracing bars, the joints being either riveted or welded. It rests on the inner channels of the end carriages. If one makes this light girder about 3 ft. deep, it will serve as a protecting fence or hand rail for the platform as well as in the capacity of an auxiliary girder.

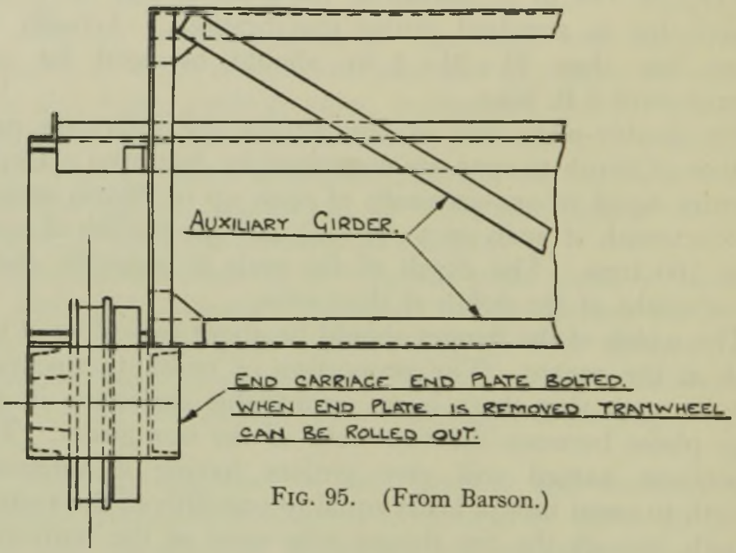

Fig. 95. (From Barson.)

END CARRIAGES OR CRADLES

The end beams or cradles and their axle bearings are subject to much variation of design. They often consist of steel channels or of joists, as shown in Fig. 96, whilst others are box girders built up from plates and angles, as in Fig. 97.

The travelling wheels and their axles are variously fitted. In many light cranes the wheels revolve on fixed axles, to reduce the cost, as in Fig. 96, using a long central boss. The best position for the wheels is between the beams, though they have sometimes been placed outside. The bearings are generally bolted on to joists, as in Fig. 98. These are either of the dead-eye form (filbores) or of the solid-plated boss

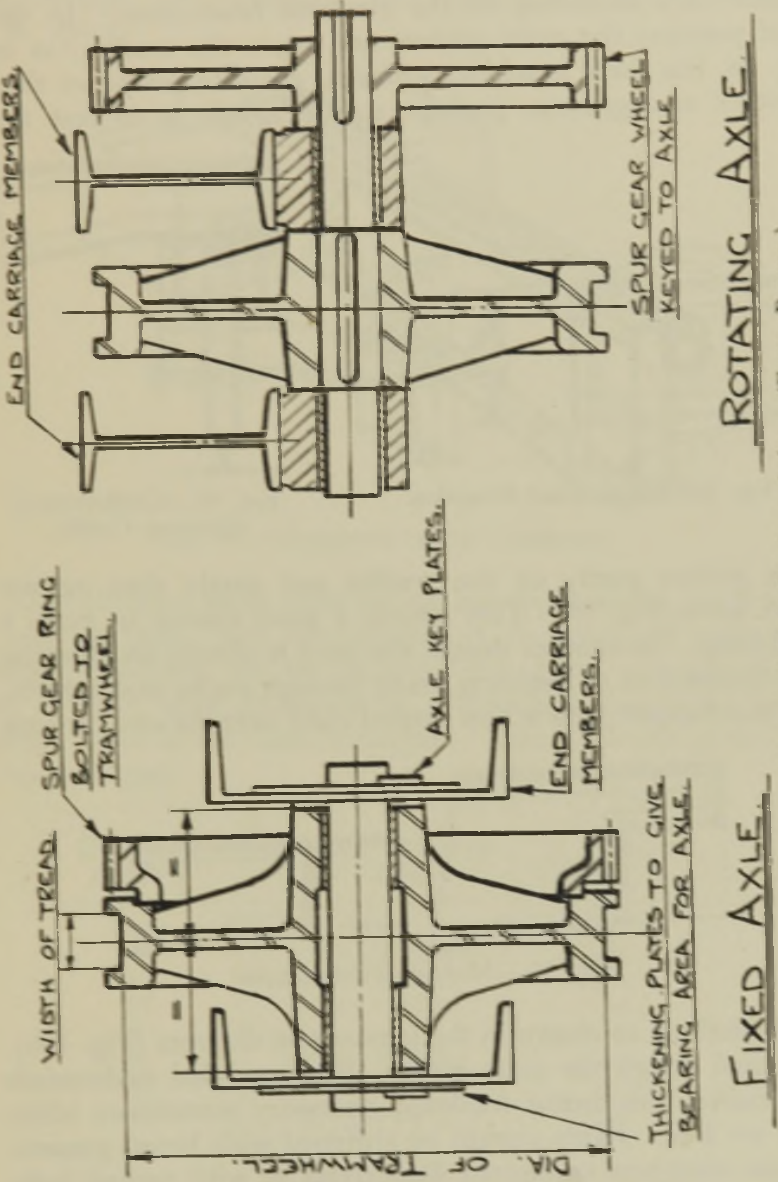

Fig. 96.—Two Types of End Carriage Axles. (From Barson.)

type known as disc bearings, and should be bushed. Bearings fitted with brass steps are less used than formerly, since the advent of ball and roller bearings, which materially reduce the friction.

The relative positions of the main girders and the end cradles vary according to the available head-room. In the ideal position the main girders rest upon the cradles, as in Fig. 98, but there is seldom sufficient room to permit of this. Another arrangement, perhaps equally good, is to rest the main girders partly on the cradles and partly abut against them, as in Fig. 99. This affords a good chance to make a solid joint. In another design the joint is simply an abutting one, the method of fastening being through angles and gussets. The top flanged plate is best carried right over the end carriage and bolted on, as shown in the perspective diagram (Fig. 100). In a final design the main girders are suspended underneath the cradles, this being rendered necessary sometimes when roofs are low. Joints should be stiffened with broad gussets, and the members connected with rivets or with turned bolts of ample size fitting in reamered holes, to prevent cross winding.

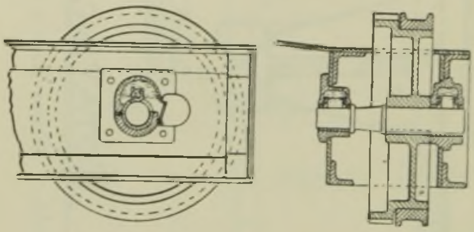

Fig. 97.—Tram-wheel Mounting.

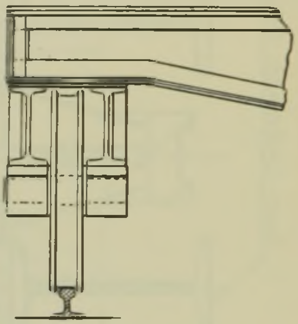

Fig. 98.—Connection of Girder to Cradle.

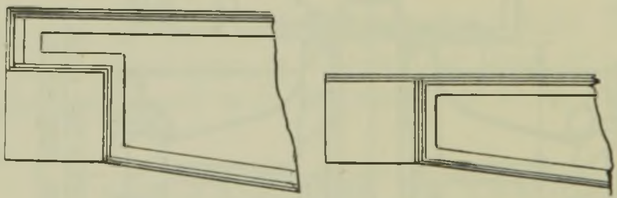

Fig. 99.—Alternative Connections.

It has already been stated that the wheel-base should be about one-fifth of the span, the crane being carried on four wheels. Cranes of over 60 tons capacity, however, preferably have *eight* travelling wheels, arranged in two bogies on each end carriage, the centres of the bogies being spaced about 11 ft. apart.

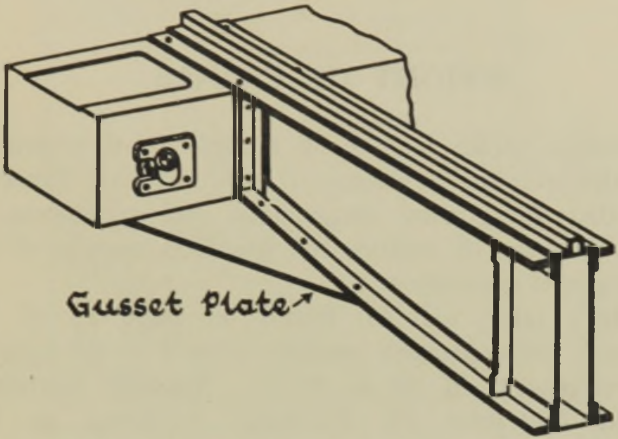

FIG. 100.—Adamson's Girder Connection.

The following short table giving the approximate loadings on end carriages, and the weights of the crabs of electric overhead travellers, will be useful for reference. It is adapted from a fuller table contained in a handbook issued by Sir William Arrol & Co. Ltd., Glasgow. Here L is the span of the crane in feet.

Capacity of of Crane	Maximum Weight on End Carriage	Approximate Weight of Crab
Tons	Tons	Tons
5	$7{\cdot}3+0{\cdot}082L$	1·9
10	$11{\cdot}7+0{\cdot}127L$	3·2
15	$17{\cdot}5+0{\cdot}125L$	3·8
20	$23{\cdot}6+0{\cdot}130L$	4·5
25	$28{\cdot}4+0{\cdot}165L$	5·5
30	$20+3{\cdot}2\sqrt{L}$	6·5
40	$28+3{\cdot}8\sqrt{L}$	9
50	$35+4{\cdot}5\sqrt{L}$	11
60	$40+5{\cdot}4\sqrt{L}$	13

For example, in the case of a 20-ton crane of 50-ft. span, the greatest weight coming on an end carriage is $23 \cdot 6 + 0 \cdot 13 \times 50$, or, say, 30 tons. In the case of a 30-ton crane the corresponding figure is $20 + 3 \cdot 2\sqrt{50}$, which equals 42·6 tons for a 50-ft. span, and becomes 44·8 tons for a 60-ft. span.

WEIGHT OF CRANES

Extensive tables have been compiled by several authors giving the weights of cranes of various lifting capacities and spans, also the general dimensions and clearances, as well as suitable sizes of motors for specified speeds of hoisting, travelling and traversing.

Such a table will be found on page 18 of Wiggle's " Cranes " for capacities ranging from 3 to 20 tons and for spans ranging from 30 to 60 ft. Another valuable table, compiled by John H. Huntley, is given in Kempe's " Engineers' Year Book " for cranes up to 100 tons in capacity.

Some *curves* showing the relation between the weights and spans for a series of cranes, ranging from 3 to 50 tons in capacity, are given by John H. Ellis in his 1936 paper on " Overhead Electric Travelling Cranes." He also gives graphs showing the maximum wheel loads of cranes by two different makers.[1]

Reference may also be made to W. A. Barson's book on " Electric Overhead Travelling Crane Design," which contains a series of charts showing the net weights of complete cranes from 1-ton up to 60-tons capacity, also maximum loads on the travelling or tram wheels and the weights of fish-bellied plate-box girders, as well as of lattice-braced main girders for cranes.

The last-named graph is reproduced in Fig. 101. Running one's finger along the 60-ft. line till it meets the 30-ton curve and then dropping one's eye to the base line, one sees that the weight of a pair of girders for a crane of that span is about 13·4 tons. Similarly one reads off the weight of girders for any other span and capacity.

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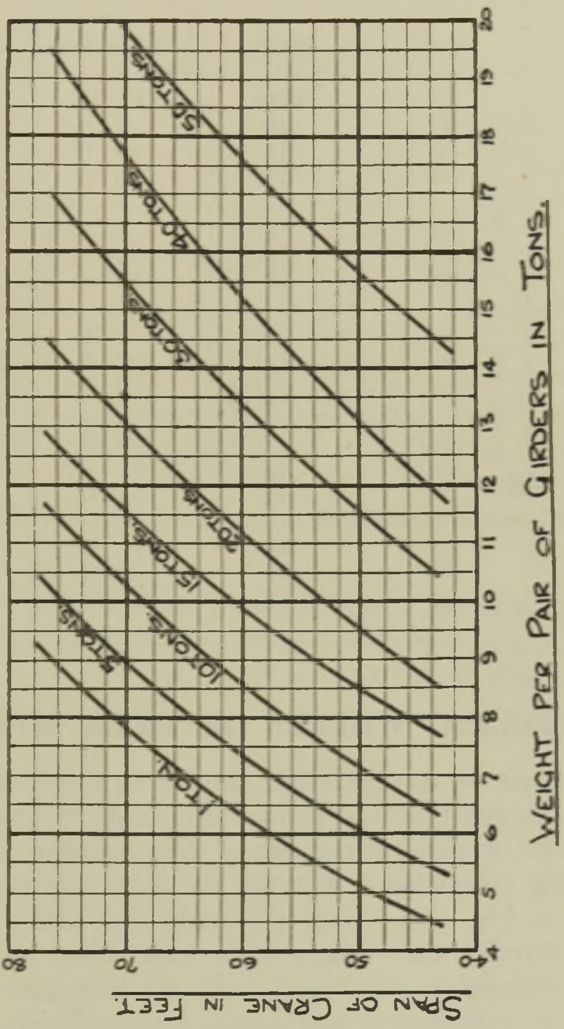
[1] See *Proc. Inst. Mech. Engineers*, vol. 137, page 284.

The following short table, giving the approximate weights of a range of cranes, has been adapted from a longer table



WEIGHTS PER PAIR OF LATTICE BRACED BOX MAIN GIRDERS.

FIG. 101.

in Barson's book. The actual weight of a crane will naturally vary somewhat with the maker and the type of girder. The centres of the tram wheels and the gauge of the crab-wheels are also tabulated.

Capacity	Span	Weight	Wheel-base	Crab Gauge
Tons	Ft.	Tons.	Ft. In.	Ft. In.
5	40 60 80	10 14 20	8 6 10 0 13 3	4 6
10	40 60 80	12 16·5 23	8 6 10 0 13 3	5 6
15	40 60 80	15 19 27	9 0 10 0 13 3	6 0
20	40 60 80	18 23 32	10 0 11 0 14 0	6 6
40	40 60 80	29 37 45	11 0 12 0 14 0	7 6

TRAVELLING WHEELS OR TRAM WHEELS

The wheels of travellers are similar to those of portable jib cranes, except that the former are made double flanged, as in Fig. 102 (to prevent the risk of their running off the rails when getting crosswise); whereas the latter are made single flanged, as in Fig. 103. They are made with arms, or plated, and steel tyred. Cast-iron wheels have been much used, sometimes ground on the treads. In the best class of work, however, the travelling or rail wheels are made either of cast steel or of cast-iron centres with steel tyres shrunk on. Cast-iron wheels are only suitable for light cheap cranes. In the armed type (Fig. 103) the arms are liable to fracture, either near the boss or next to the rim, under the shocks of severe duty.

A better form of cast-iron wheel is that with the solid plated centre (Fig. 104) in which the ribs may or may not be retained. They help to support the rim, and if omitted the web must be thickened. The treads of such wheels are subject to rapid wear, which is not equal all over, but produces deep grooves. This results in irregular running and ultimately in fracture. If the rims are made thicker, to leave allowance for returning, then they become too thick to permit of regular shrinkage. This is liable to set up internal tension that may cause fracture in service.

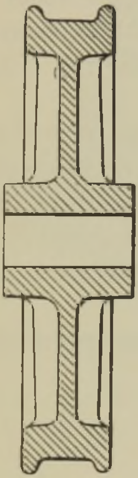


FIG. 102.—Double-flanged Wheel.

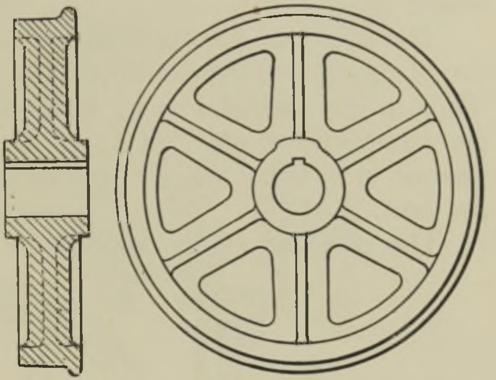


FIG. 103.—Single-flanged Wheel.

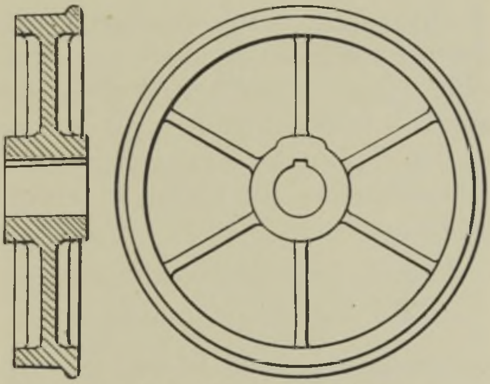


FIG. 104.—Solid Plated Wheel.

In the majority of good cranes the steel-tyred wheels (Fig. 105) are used, both for portable and travelling cranes. They are strong, safe and very durable. The centres are either of cast iron or cast steel, while the tyres are shrunk on. The tightening of the tyre due to shrinkage as it cools around the centre, together with the shallow check, are sufficient to retain the tyre in place without any further aid from tyre bolts. The shrinkage allowance varies from 35 thousandths of an inch for a 24-in. wheel to 40 thousandths for a 36-in. wheel.

The safe load on a cast-steel wheel in pounds is 800 times the diameter in inches multiplied by the width of rail contact. Thus in the case of a 24-in. wheel and a rail face of $2\frac{1}{4}$ in. we get a safe load of $800 \times 24 \times 2{\cdot}25$ lb., or, say, 19 tons. In the case of steel-tyred wheels the load may be increased by 50 per cent.

The constant 800 is suitable for a travelling speed of 100 ft. per min. As the speed goes up this factor should go down, until it falls to 600 for a speed of 300 ft. per minute.

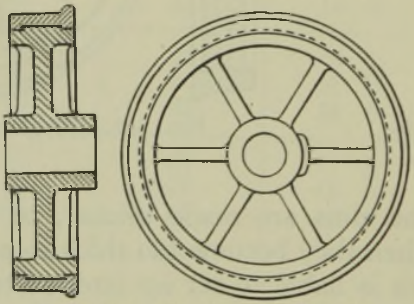


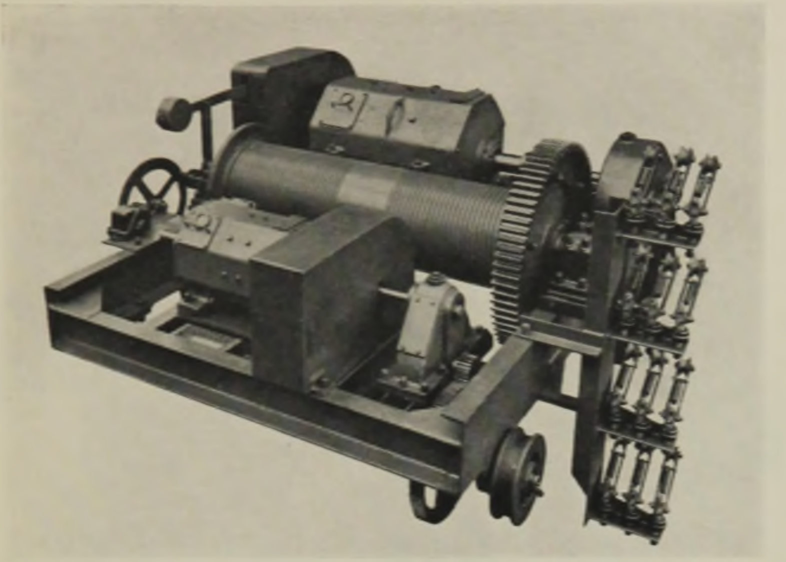
FIG. 105.—Steel-tyred Wheel.

For a double-flanged wheel running on standard bridge rails, a normal width between flanges is 2 in. for a rail section of 40 lb. per yard and $2\frac{3}{4}$ in. for a rail weighing 70 lb. per yard.

According to Adamson, the allowable wheel load in tons is given by the relation

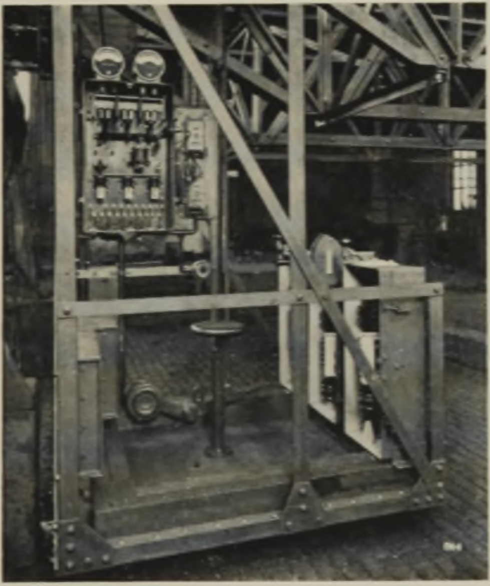
$$\frac{8 \times \text{diameter of wheel} \times \text{width of tread}}{\text{Revolutions per minute}},$$

the dimensions being expressed in inches. In his practice the usual construction for longitudinal travelling wheels is to shrink rolled-steel tyres on cast-iron centres, with machine-cut spur rims of steel bolted to the centres, as seen in Fig. 106, in preference to *keying* spur-wheels on to the axles ; thus avoiding the use of keys at a point where there is the greatest



Joseph Booth & Bros. Ltd.

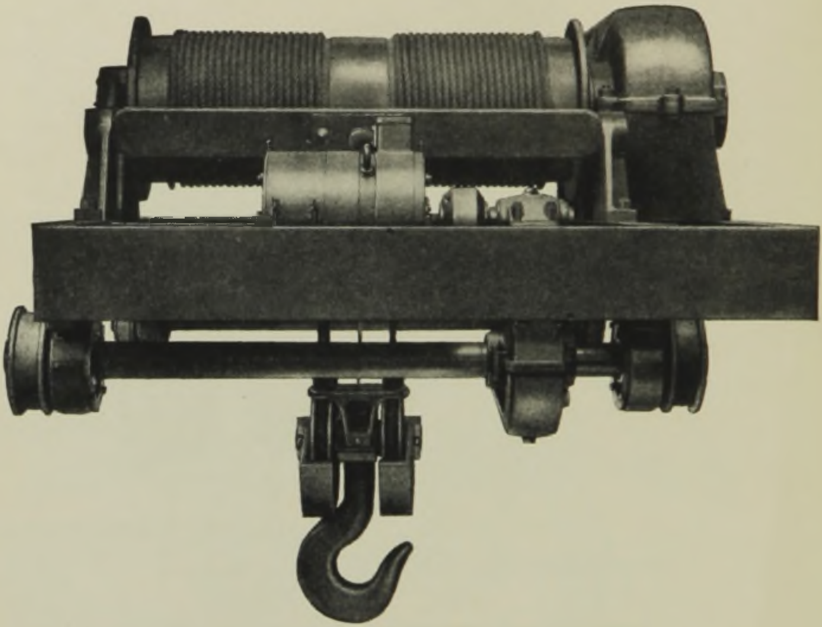
STEELWORKS CRAB WITH COLLECTOR BRACKET.



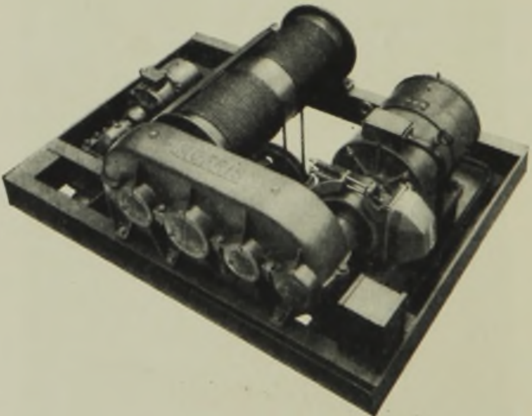
CRANE CAGE SHOWING PANEL AND CONTROLLERS
WITH COVERS REMOVED.

[*To face page* 160.

PLATE 24



SIDE VIEW OF TRAVELLER CRAB.



LIGHT ELECTRIC CRAB WITH ENCLOSED GEARS.

To face page 161.]

risk of failure due to frequent reversals of the crane, causing the wheel to work loose on its key. In a rather earlier design of Adamson crane (Fig. 97) the cast-iron centre and the spur-wheel blank were cast in one piece.

Since the load on the outer end of the axle is greater than that on the inner end, the axle is enlarged there. A self-oiling device is also adopted; the axle revolves in a gun-metal bush, cut away on the under side in order to communicate with the lower part of the pedestal, forming an oil reservoir. The oil is constantly carried up against the axle by a wooden roller floating on its surface and retained beneath the axle by guides cast within the chamber. A flap door gives access to the oil chamber. Roller bearings are now available as a desirable alternative to bushed bearings.

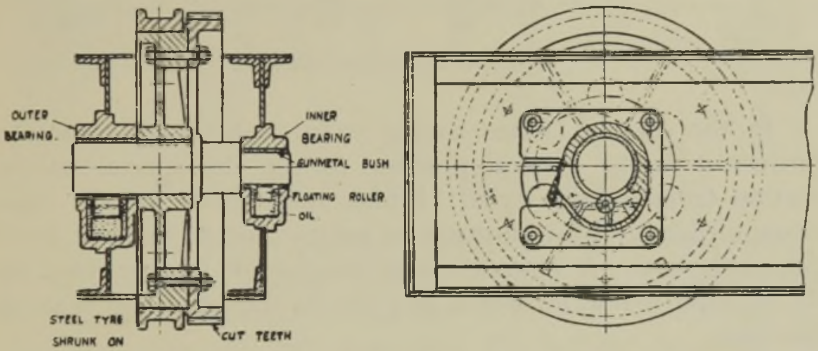


FIG. 106.—Adamson's Tram Wheel and Axle.

About a generation ago Daniel Adamson established the sizes given in the table on page 162 for the travelling wheels and axles of overhead cranes made by his firm Joseph Adamson & Co., of Hyde. The span was taken as 50 ft. in all cases. The stress in the axles due to bending here ranges between 4 and 5 tons per sq. in. The projected area of the bearings is such that the bearing pressure $\times \sqrt{\text{the velocity}}$ does not exceed 900, the bearing pressure being expressed in pounds per square inch and the rubbing velocity in feet per second.

Rails.—In light cranes up to, say, 10 tons in capacity it suffices to rivet a steel bar $1\frac{1}{2}$ in. square to the top of each joist, in order to form a track for the cross traverse of the crab. High carbon steel should be used for this purpose to ensure reasonable durability.

Crane Capacity	Diameter of Wheel	Width of Bearing on Rail	Wheel Load	Diameter of Bearings	
				Inner	Outer
	In.	In.	Tons	In.	In.
3	18	1½	4½	2	2½
5	18	1½	6	2	2½
10	24	2	9¼	2	3
15	24	2	12½	2½	4
20	24	2	16	2½	4
25	30	2	19½	2½	4
30	30	2⅜	22½	3	5
40	30	2⅜	29	3	5
50	36	2⅜	36	4	6

In the case of cranes having either box or lattice-braced girders it is the general practice to use the special hollow section flanged rails styled ‘ bridge rails,’ both for the main crane girders and the runways or gantry girders running down the shop bay. A common size weighs 56 lb. per yard by 2⅝ in. high, while its width is 2 in. on the head and 6 in. at the base.

The lightest British standard bridge rail that is rolled weighs 14 lb. per yard, whereas the heaviest section is 70 lb. per yard by 3 in. high. For a 10-ton or a 15-ton crane a suitable section of bridge rail weighs 24 lb. per yard.

For exceptionally heavy work, solid flat-bottom rails are obtainable from continental sources. These foreign rails are rolled in metric units only, the range of sizes being from about 5 to 9 in. wide across the base and from about 45 to 205 lb. per yard in weight.

Gantries or Runways. — Crane gantries must be laid straight and level and as nearly parallel as possible, so that only a minimum of side clearance is necessary between the rails and the tram-wheel flanges, otherwise the crane will coast from side to side and undue wear will result. The joints of the rails should overlap, by fully 1 ft., the joints in the supporting joists, which must be securely fastened to the columns.

Gantry joists must be sufficiently stiff laterally to resist the horizontal forces caused by occasionally dragging loads from adjoining bays, as well as the forces due to inertia when stopping and starting the crab in normal working.

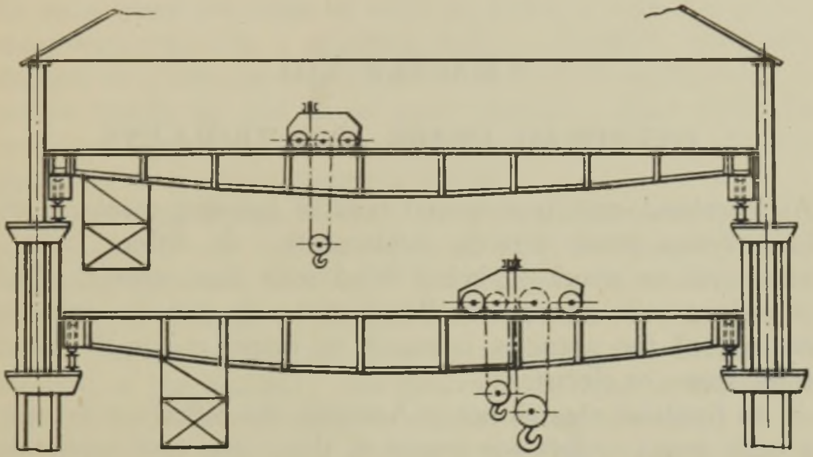


FIG. 107.—High and Low Level Workshop Cranes.

As mentioned by Adamson, it is a good plan when building engineering shops to provide a second high-level gantry running the full length of the bay (Fig. 107). The upper or auxiliary crane can then pass over the heavier crane on the lower gantry and so serve either end of the shop as may be needed, as well as being available when overhauling the larger crane.

NOTE.—There is a good drawing of an Adamson 120-ton electric overhead traveller in *The Engineer* of 30th August 1912.

CHAPTER XIII

OVERHEAD CRABS AND TROLLEYS

An overhead crab is a special type of hoisting machine, the load being lifted directly underneath. It differs from a fixed crab or winch in being fitted with four wheels, which run along rails on its traveller beams. It may be operated by any of the agencies common to cranes; namely, hand, rope, steam or electricity.

In England, though not in America, the difference between a crab and a trolley (or jenny) is this: the *crab* carries its own operative gears or is self-propelled, whereas the *trolley* is not. Though both travel along rails, the crab is moved by its own self-contained gearing, whereas the other is drawn along by chains or by ropes, which are actuated by gearing placed at the end of the traveller beam.

Just which is the more suitable device is an open question, and practice is divided. For light and heavy loads alike both methods of traversing the load are in use. Speaking broadly, it is better to use the simple trolley for light travellers and crabs for the heavier ones. Yet there are cases in which heavy travellers are fitted with trolleys, which in long spans impose less weight on the girders of the traveller than a massive crab would do, especially if this carries an engine and boiler. It is otherwise in the case of electrically operated cranes.

Crab Cheeks.—The cheeks or sides of trolleys and crabs were formerly made in cast iron, except in the largest sizes, which were steel plated. But nowadays joists and channels are commonly employed. In some steel-plated cheeks the plates are double, separated by distance-pieces. This is an excellent method, having the merit of rigidity, and permitting of the use of bearings which are nearly flush with the outer faces of the plates.

In some crabs the cheeks are formed of steel joists and in others of built-up plated girders. Underlying these diversities in design are common objects in view, the two predominant factors being reduction in weight and economy of manufacture. In most cases the class of work in which a firm has gained most experience is a deciding factor. Actually, successful designs of cheeks have been produced both in castings and in plated cheeks as well as in steel sections. Apart from inspection, the reputation of the maker is still often the best guarantee of the good design of a crab.

Hand and Steam Crabs.—In a simple hand crab all the movements of the crab are derived from the power of men actuating the winch handles. The lifting mechanism includes double gear, though treble gears are included in the heaviest crabs. Lowering may be done by reversing the direction of rotation of the handles ; but generally the load is allowed to descend by its own weight, its motion being controlled by the application of a brake. During lifting the ratchet-pawl is thrown into contact with the ratchet-wheel. During lowering the pawl is thrown back, and the first motion pinion is slid along the shaft out of gear, so that the descent of the load is regulated by the brake entirely.

The last detail in the train is the lifting drum or barrel, whence loads from about 3 to 5 tons are lifted on a single chain or rope, and for greater loads on two falls of chain or rope with a hook-block. In small crabs the chain drum is often plain, in others grooved. When wire rope is used the drum is always grooved. The reason for grooving drums is partly to prevent overriding, but chiefly to maintain the load centrally in relation to the crab. When a return chain is used, one end has to be anchored from a beam overhead.

Another set of gearing is used for traversing the crab along the traveller beams. This cross-traverse gear may be either simple or compound, according to the load. It is actuated by separate winch handles in a hand crab, and by a separate motor in an electric crab. The motion of the gears is transmitted to a spur-wheel keyed on the axle below and so turns the axle and its wheels on the rails. The second axle is a trailer only. In the case of some heavy steam crabs the front and rear axles have been coupled together by a rod, as are locomotive axles.

Figs. 108 and 109 represent a hand crab with steel-plated cheeks. Here some of the shaft bearings are plummer-blocks, but most of them are disc bearings. The quick-lifting gears are the pinion A and the spur-wheel B, the latter being keyed on one end of the drum C. The train of slow gears for heavier loads include D and E. Carried on a steel joist spanning the crab cheeks is a pillow-block G, from which are suspended the straps and blocks carrying the chain sheave H. This takes the upper bight of the chain J, one part of which is anchored to the hook-block below and the other part passes under its sheave. The spur-wheels K, L, M and N form a compound train of gears for traversing the crab.

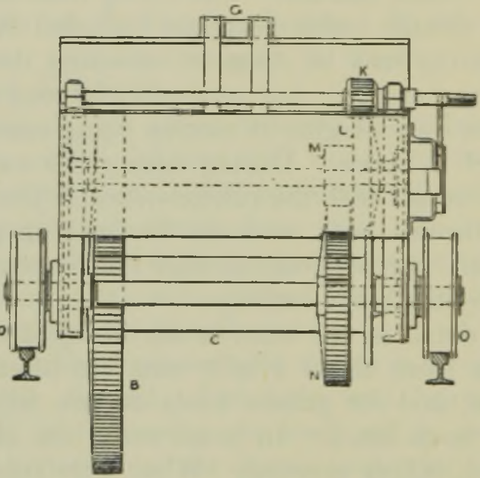


Fig. 108.—Hand-operated Crab.

The position of the *hand brake* is indicated at Q and of its lever at P. In single-geared crabs the brake drum goes on the same shaft as the lifting drum and the large spur-wheel, often on the wheel itself. It is then desirable to make the pinion capable of sliding in and out of gear with its spur-wheel, because it is better when lowering with the brake to avoid wear and tear and noise, by allowing only the wheel and the lifting drum to revolve. When the pinion of a hand crane cannot be thrown out of gear, the handles of a hand crab should be taken off before lowering. Up to four men may operate on winch handles at one time.

In the case of a steam crane, if there were no sliding pinion the lowering could not be done by means of the brake. The engines would have to be reversed, which would be a slow, noisy and wasteful method of lowering the load.

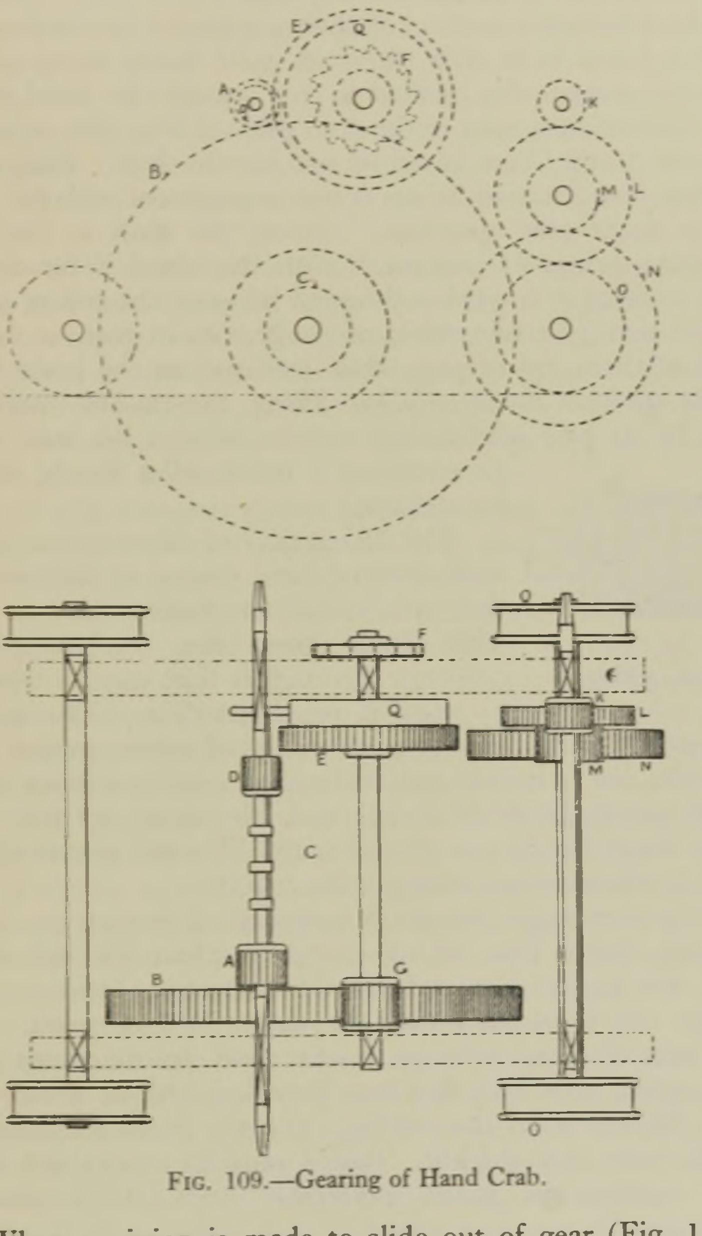


Fig. 109.—Gearing of Hand Crab.

When a pinion is made to slide out of gear (Fig. 110) it has to move along a feather key, and a collar or a groove is provided at one end to receive the fork of the lever by which it is moved. The teeth of the pinion are often rounded slightly at the entering end, in order to facilitate meshing without the risk of knocking off the tooth points.

An alternative method of sliding a pinion into engagement with a wheel is to slide the shaft itself bodily along with its pinions, though this method is only suitable for hand cranes. An illustration is seen in the crab gears of Fig. 109, where the pinions A and D are keyed on one handle shaft. Sliding this shaft in one direction brings A into engagement with the wheel B for single-gear operation. Sliding the shaft in the other direction brings D into mesh with the wheel E for double-gear working. A pawl is dropped between the collars on the pinion shaft to retain either of the pinions in gear, or to keep both of them out of gear while lowering on the brake Q, as in the position shown. When lifting, the ratchet wheel F is held by its pawl and cannot reverse, so that the load would be sustained if the handles should slip off by accident.

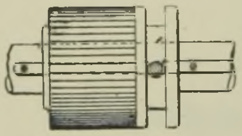


FIG. 110.
Sliding Pinion.

The lifting gear of *steam* cranes differs from that of *hand* cranes in this respect, that much heavier loads can be lifted with single gear, due to the greater power in the engines than can be exercised by men at winch handles. The gain is also greatly in favour of *speed* as well as of power, so that fairly big loads can be hoisted rapidly in single gear by a steam crane, which would be lifted slowly and laboriously by four men at the winch handles on a hand crane. Double gear is seldom fitted to steam cranes lifting under 5 tons.

It is even more important to put good gearing on quick-running cranes than on hand cranes, where the defects of gears are partly disguised by the slowness of the motion, though this does not justify the use of inferior gears. The high rates of speed common in steam and electric cranes cause some noise, even with the best moulded wheels, whilst with badly formed teeth the rattling becomes intolerable and the wheels wear out quickly. Hence modern cranes are fitted with machine-cut gears, preferably enclosed in oil-tight gear cases.

The use of steel for gears is very desirable in cranes that have to do much rough work for which both strength and durability are required. Though they cost double those of cast iron and are of rougher surface they last more than twice as long. Nor is that the only advantage. The liability of steel wheels to fracture is so slight that the risk of stoppages for repairs is much lessened. For a slow drive a forged-steel pinion, with the teeth machine cut, often works well with a sound machine-moulded cast-iron spur-wheel. When cast-steel gears are used it is desirable to keep spares, because steel wheels are much slower in delivery than cast-iron wheels.

At one time flat link *steel chain* was used to a considerable extent as a load chain for crabs up to about 20 tons capacity and even higher on the Continent. Such a chain permits of a small and compact crab being designed. Its great drawback is its lack of flexibility, save in one plane only. Hence chains have been displaced by wire ropes, which are much more flexible as well as cheaper.

Formerly travellers driven by cotton ropes were extensively employed, but are now obsolete. In a *rope-driven crane* there is a headstock at one end of the girders, carrying the rope pulleys and belt pulleys for open and crossed belts. These drive two shafts running a little above the top of the crane girders, whence the lifting and traversing motions of the crab are derived through worm gears. Some of these old rope cranes were converted into single-motor electric cranes before the three-motor cranes were developed.

It is of historical interest to note that at the Paris Exposition of 1889 there were exhibited two 10-ton single-motor overhead travellers as well as a small crane fitted with two motors, one for lifting and the other for travelling. But the first commercial three-motor electric traveller was designed by an American engineer, Mr A. S. Shaw, and constructed in 1889 by the Edward P. Allis Company, of Milwaukee.

Electric Crabs.—A modern electric crab carries at least two motors, one being used for traversing the crab and another for lifting the load, while a third is often fitted for operating an auxiliary hoist for light loads. In addition a fixed motor is provided for the longitudinal travel motion.

The diagram [1] (Fig. 111) indicates a layout of lifting gear,

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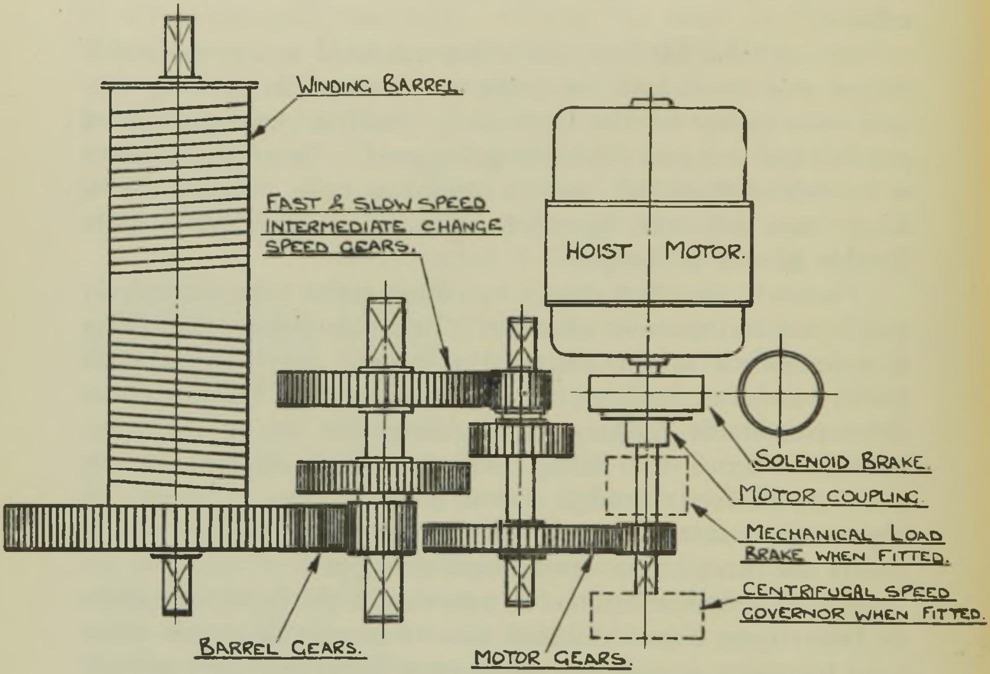
[1] This and a few other illustrations are taken from Barson's "Electric Overhead Travelling Crane Design," with Mr Barson's approval.

or hoist machinery, where the motor shaft is coupled to a short extension shaft carrying a solenoid brake, also the first-motion pinion and usually a centrifugal speed governor. This governor is adjusted to limit the *lowering* speed to not more than twice the normal *hoisting* speed. Cranes running on alternating current, however, need no centrifugal governor, as 3-phase motors will not race ; so that the lowering speed in such cranes does not much exceed the hoisting speed.



ARRANGEMENT OF HOIST MACHINERY.

FIG. 111.

On most crabs the average service loads are generally much below the full load for which the crane is designed, hence a change-speed gear is provided for handling light loads faster than the full load. Full load lifting speeds range from 20 to 30 ft. per min. for 5-ton loads, falling to 15 ft. for 10-ton loads, 10 ft. for 25-ton loads, and so on down to, say, 4 ft. per min. for the heaviest loads.

A convenient speed for the hoist motor is between 500 and 750 revs. per min. To find the horse-power of this motor one simply takes a tenth of the foot-tons of work at the hook. For example, a crab lifting 20 tons at the rate of 10 ft. per min. will need a hoist motor of 20 × 10 ÷ 10 or 20 H.P.

The basis of this short and handy rule is interesting. It is always useful to get down to first principles. Neglecting friction, the gravity horse-power alone is

$$\frac{\text{The force in pounds} \times \text{the distance in feet per minute}}{33000}$$

$$=\frac{\text{W tons} \times 2240 \times \text{S ft.}}{33000}$$

$$=\frac{W \times S}{14 \cdot 7} \text{ or } \frac{W \times S}{C}.$$

If we take C as 10, this means that we are assuming a transmissive efficiency of 10 ÷ 14·7, which is 0·68 or 68 per cent. This allows for friction. Thus the required horse-power of the motor is a tenth of the product of the load into the speed.

Cross-traverse Gear.—Fig. 112 indicates a layout of the traversing mechanism often adopted for medium-gauge crabs up to, say, 50-ton capacity. Each axle carries two cast-steel flanged wheels or "runners," which are overhung. The runners may be about 9 in. diameter for a 3-ton crab, 12 in. for a 15-ton crab and 18 in. diameter for a 40-ton crab, rising to 24 in. for a crab of 100 tons lifting capacity. One axle only is positively driven by the traverse motor through a train of spur-wheels.

Although a solenoid brake is indicated in the diagram, it is only in special cases that a traverse brake is needed, as when high speed is combined with a short span. A brake should be fitted, however, when the speed of traverse exceeds 100 ft. per minute.

The axle bearings are usually bronze bushed, in which case the tractive effort will be about 70 lb. per ton of total load. This figure can be much reduced, however, by fitting *roller* bearings. The necessary power of the cross-traverse motor is given by the simple formula

$$\text{H.P.} = \frac{W \times T \times S}{33000 \times e},$$

where W (tons) = weight of crab and load,
T (lb. per ton) = tractive effort or resistance,
S (ft. per min.) = speed of traverse,
e = efficiency of transmission.

Thus in the case of a 20-ton crab moving at 80 ft. a min. and weighing 5 tons, and whose traverse mechanism has an efficiency of 0·7, with axles running in bronze bearings, we have

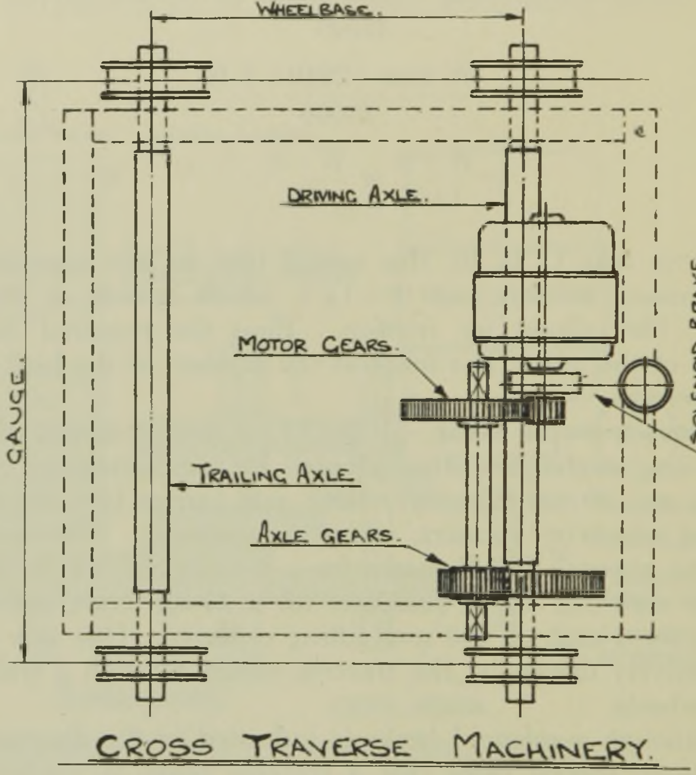


FIG. 112.

$$\text{H.P.} = \frac{(20+5)70 \times 80}{33000 \times 0{\cdot}7} = 6.$$

Crabs for very large cranes are designed with an extra wide gauge and with the runner wheels mounted and driven in much the same way as are the bridge tram wheels on the longitudinal travel motion.

In Daniel Adamson's Manchester paper of 1925 he gave the following sizes of crab runners and axles as having proved satisfactory after twenty-five years' experience :—

Crane Load	Wheel Diameter	Axle Diameter	Max. Load per Wheel
Tons	In.	In.	Tons
3	12	2¼	1¼
5	12	2½	1¾
10	12	2¾	3¼
15	14	3¼	4¾
20	14	3½	6¼
25	16	3¾	8
30	16	4	9½
40	18	4½	12½
50	18	5	15½

As regards the crab frame, the present-day practice is to build it up from rolled-steel sections, for the sake of accessibility and ease of manufacture. Adamson preferred construction of crab sides, however, was to use double-steel plates with the bearings riveted between them, thus ensuring correct original alignment and permanence for the position of the bearings, as compared with crabs built up of standard sections with loose pedestals. The steel plates range in thickness from ¼ to ½ in. and are spaced 2 in. apart for crabs up to 50 tons capacity, rising to ¾-in. plates at 4 in. gap for 100-tonners. See Plates 22 to 25 for various examples of crabs.

Bearings of Shafts.—Crab bearings should be lined with renewable bushes about ⅜ in. thick and grooved for lubrication, though the bushes of axle bearings may be made rather thicker with advantage.

In order to satisfy the B.S.S. No. 466 (1932) for electric overhead travelling cranes the bearings for high-speed shafts must be of the ball, the roller or the ring-lubricated type. Ball and roller bearings must be mounted in dust-proof housings and lubricated by a grease gun. Ring-lubricated bearings must have oil reservoirs and drain plugs, inspection covers being chained to their bearings. Bearings for slow-speed shafts should have adjustable caps where feasible and be fitted with Stauffer grease lubricators. The base should be machined.

Though several examples of solid-bearing or ‘ dead eyes ’ have been shown in previous illustrations, yet split bearings fitted with brasses (or steps) are far preferable, as seen in Fig. 113. To prevent these from turning round a stud is cast on one step, entering into a drilled hole in its circular seating. Studs are used to hold the cap down and an oil cup is cast on the cap. Either a Stauffer grease lubricator may be fitted or a Tecalemit nipple for grease-gun lubrication.

In Fig. 114 the steps are divided obliquely, and the cap has no check but abuts simply on the face of the bearing. In many bearings the top step is square and the cap is a plain rectangular piece of steel.

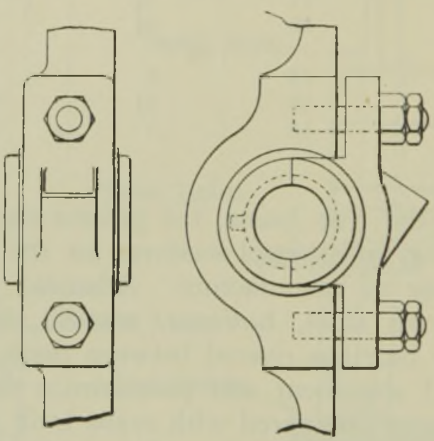


FIG. 113.—Step Bearing Split Vertically.

The bearings fitted to plated cheeks may be of the disc type (Fig. 115), consisting of a cast-iron boss with a round or square flange, bolted to the plate and spigoted into it. A drawback to disc bearings is that no provision exists for closing them round their shafts to compensate for wear, but it is easy to renew their brass bushes when worn.

Another objection is that shafts can only be withdrawn from disc bearings *endwise*, thus causing much loss of time and inconvenience when pinions or other details need renewal. Hence it is better to make provision for adjusting bearings and for removing shafts by means of brasses and caps. The pattern bearing is first fitted round the angle iron forming the edge or fillet of the plate and the casting is bolted through the angle and the plate. If *bolts* are used for the caps, instead of studs, the holes are cored out to form recesses for the heads and are reamed to fit the stems of the bolts.

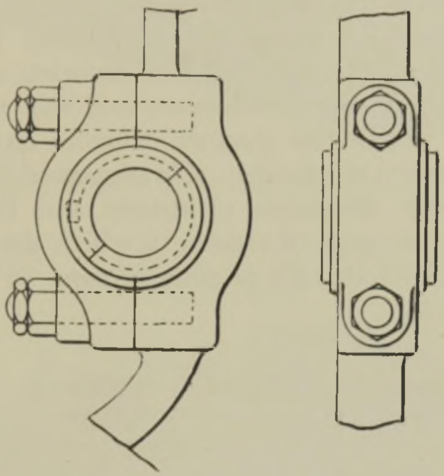


Fig. 114.—Step Bearing Split Obliquely.

Fig. 116 shows a bearing fitted against an angle at a straight length, the boss going through the plate. In practice it is often possible to include two or more adjacent bearings in one casting bolted to the edge of a plated cheek. In some designs the cheeks are neither castings nor platework, but are simply horizontal channels or built-up rolled-steel sections.

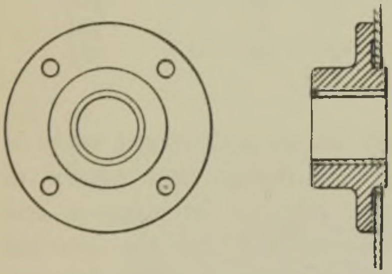


Fig. 115.—Bushed Disc Bearing.

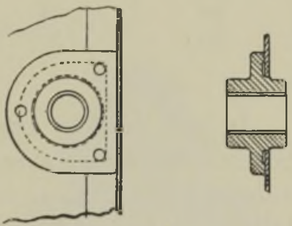


Fig. 116.—Disc Bearing Fitted to Angle.

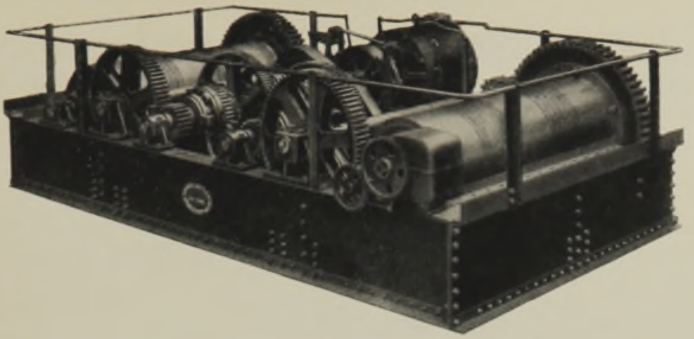
Amongst the many merits of ball and roller bearings, which are now so much used, are ease of lubrication and cleanliness, compactness, dust-tightness and high mechanical efficiency. Their convenience in manufacture, if not their cheapness, is undoubted. Yet if spare parts are not available, when renewals are needed in some remote district, there will naturally be serious trouble ; as making new ball bearings is certainly not a feasible job for an ordinary repair shop.

Size of Drums or Barrels.—In modern cranes the importance is generally recognized of making the hoisting drum of adequate size, for the sake of securing a reasonable life of the wire-lifting rope. Adamson said that the diameter of a drum should not be less than six or seven circumferences (or 18 to 20 diameters) of its rope. He suggested the following sizes of ropes, also diameters of drums and bottom-block sheaves for a limited range of cranes, in which the load on the hook is sustained by four falls or plies of rope, in the manner indicated by Fig. 79.

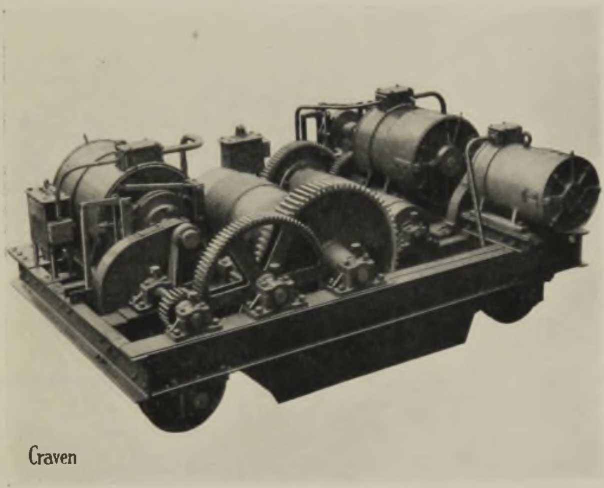
Capacity of Crane	Circumference of Rope	Pitch of Grooves	Diameter of Drum	Diameter of Block Sheaves
Tons	In.	In.	In.	In.
3	1¼	¾	9	11
5	1⅝	13/16	11	12½
10	2¼	1	14½	16
15	2¾	1⅛	16½	19
20	3¼	1 5/16	19½	22
25	3½	1½	21	24
30	4	1⅝	24	29½
40	4½	1¾	27	29½
50	5	2	30	31½

In still heavier cranes one may adopt a different style of bottom-block, as shown in Fig. 80, a design that admits of indefinite extension as regards the number of sheaves and falls of rope, and is therefore more suitable for the heaviest cranes, though it requires more head-room. The 120-ton short-pattern block depicted on Plate 26, however, is a noteworthy exception.

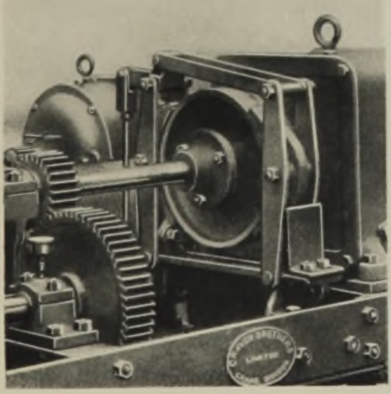
NOTE.—Barson's book on "Electric Overhead Travelling Crane Design" contains wiring diagrams for cranes driven by three types of motors.



CRAB FOR 50-TON DOUBLE-TROLLEY LADLE CRANE.



100-TON 3-MOTOR CRAB WITH OPEN GEARS.



MAGNETIC BRAKE.

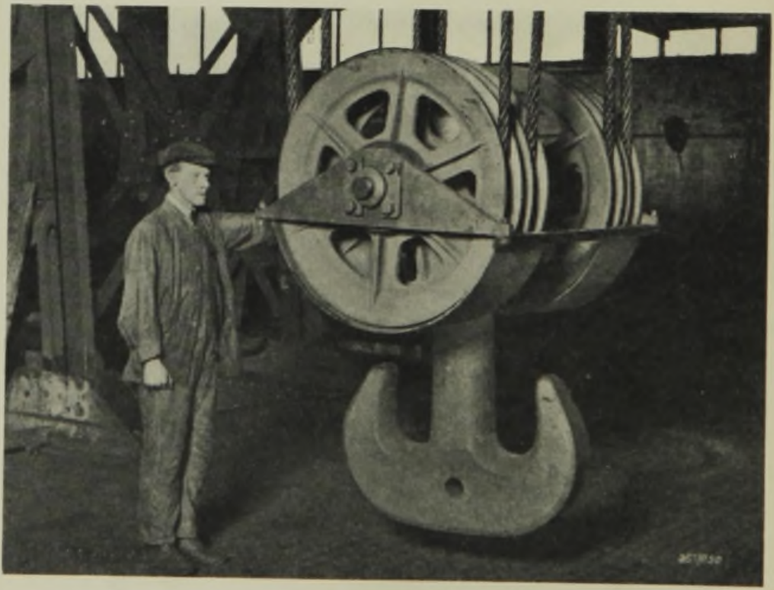
20-TON TURNOVER GEAR.

[*To face page* 176.

PLATE 26

Craven Bros. Crane Division Ltd.

120-TON 5-MOTOR STEEL FOUNDRY CRANE.



Joseph Booth & Bros.

120-TON BOTTOM OR HOOK BLOCK.

To face page 177.]

CHAPTER XIV

GOLIATHS, TITANS AND MAMMOTHS

Goliaths are bridge cranes mounted on long legs or trestles coming down to the track rails, in order to eliminate the expense and inconvenience of a long elevated gantry, as required by the usual overhead traveller. They are much used in open yards for general purposes, but more especially for handling bulky timber and for transferring heavy goods from railway wagons to motor vehicles or vice versa. They are also useful in contractors' yards and in the yards of engineering works over erection and storage ground. Sometimes the ends of a Goliath crane are cantilevered out well beyond the trackway, so as to increase its range and general utility.

Although the biblical Goliath was a giant, it does not follow that all cranes bearing that name are very big ; indeed some of them are quite small.

On the other hand a Titan is a highly specialized form of cantilever crane, always of considerable magnitude, and employed solely for concrete block-setting operations in connection with the construction of breakwaters in harbour works. Though mounted on wheels, a Titan is less mobile than a Goliath, the truck being moved infrequently from one position to another. Moreover, a Titan crane is almost always driven by steam, whereas a Goliath is commonly operated either by hand or by electricity, though many Goliaths were formerly driven by steam engines.

In Goliaths the load may be suspended either from a simple trolley, hauled along by means of a chain or a rope, or from a self-moving crab, whereas in Titans crabs are never employed. The load trolley or jenny moves to and fro freely along a horizontal jib or boom, the machinery for controlling its position being housed at one end of the structure. The entire superstructure rotates or slews on a ring of live rollers.

The terminology of cranes is not altogether free from ambiguity, partly owing to the variation of the local and national usage of technical terms. Thus in England ‘ Goliath ’ always signifies a bridge type of crane carrying either a self-moving crab or a simple trolley, whereas in America the term ‘ Gantry crane ’ is commonly applied to this type.

To such cranes the term ‘ Portal ’ is now applied, the type having been introduced from Germany. Portal cranes are employed to a vast extent for dock and harbour work, supplanting the older wharf and hydraulic cranes.

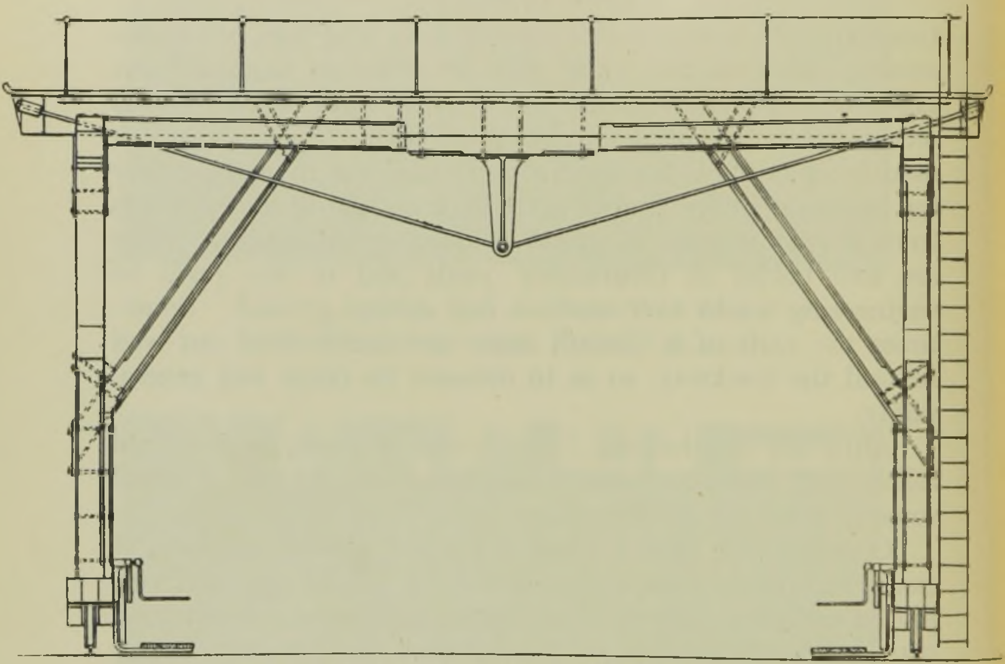


FIG. 117.—Hand Goliath with Timber Frame.

Though gantry cranes are always built of steel the framing of Goliaths have sometimes been constructed of timber, more especially when hand operated, and trussed by tie-rods, as indicated in Figs. 117 and 118. The usual height of these structures is about 25 ft., while the span ranges from 20 to 40 ft. The ample length of wheel-base will be noticed, and double-flanged running wheels are fitted. Platforms, protected with hand rails, are carried on plated brackets at the sides of the main beams.

Unless a Goliath framing is well braced the wheels are apt to get off the rails. The end framings are stiff enough, the weak points being the attachments of the main beams to the A frames. In order to stiffen these against working to and fro at right angles to the track, large diagonals are fitted between these members. Diagonal struts are also fitted between the under sides of the main beams and the tops of the horizontal members of the A frames.

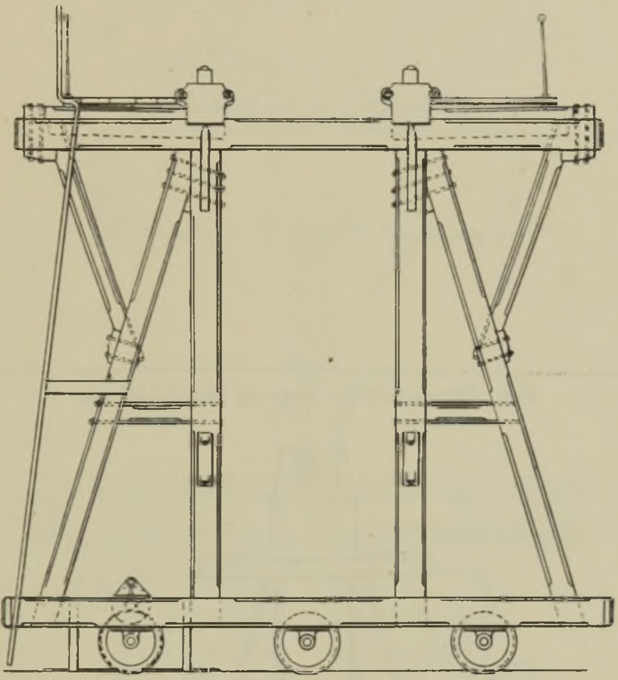


Fig. 118.—End View of Goliath.

Figs. 119 and 120 illustrate a simple trolley form of hand Goliath with steel frame, where the diagonal struts are well seen. The cross-traverse motion of the trolley is operated by chain from the right-hand end of the frame, while a double-geared hoisting drum is carried by the uprights at the other end. The travelling gear is actuated by a man standing on the ground at each end of the crane. A detail of the trolley is given in Fig. 121, showing an elevation and a plan view.

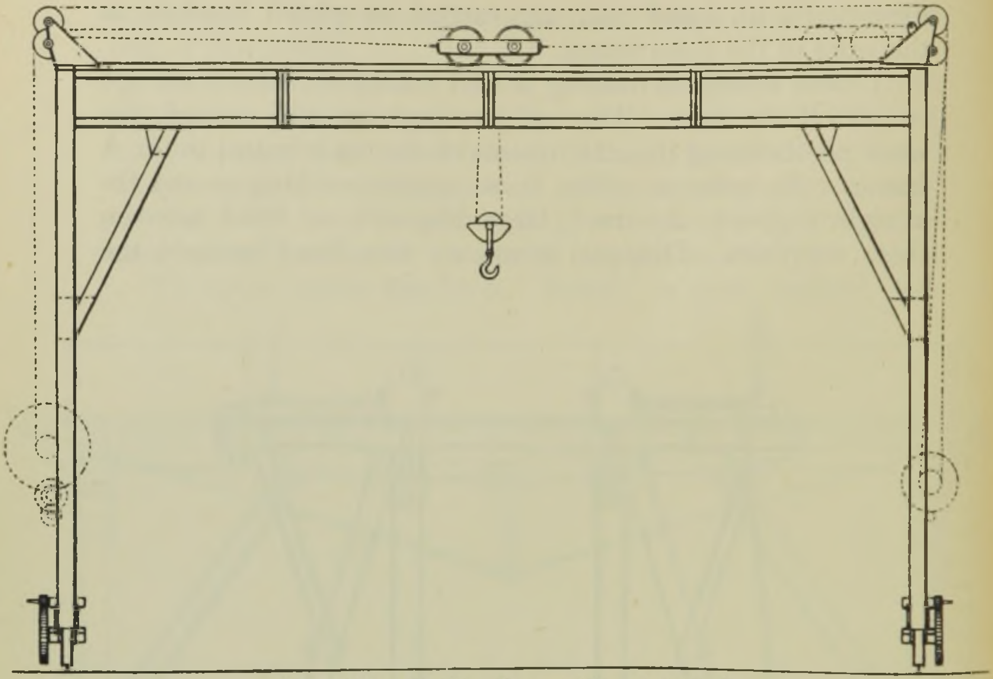


Fig. 119.—Trolley Type of Hand Goliath.

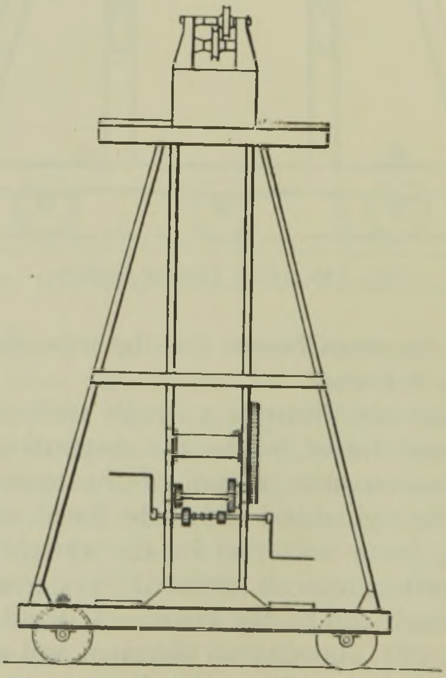


Fig. 120.—End View of Light Goliath.

Larger Goliaths can be travelled from the crab with a square shaft, but the movement has to be transmitted either through pitch chain and sprocket-wheels or by shafts and bevel gears from the top to the bottom of one or both of the end frames. Moreover, Goliaths have been made in which the crabs have been operated from the ground with pendent ropes, passing over grooved pulleys, as in some overhead travellers.

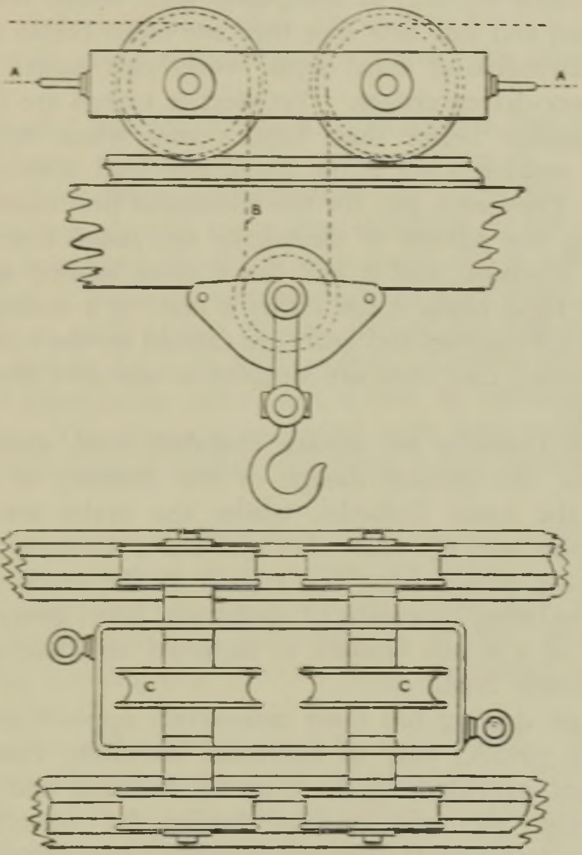


FIG. 121.—Detail of Trolley or Jenny.

As regards essential mechanism, there is no difference between travellers worked by men on the platform above or by men standing on the ground below. The question of operating cranes above or below is decided partly by the magnitude of the load to be lifted and partly by the nature of the service, whether intermittent or constant. Light cranes used intermittently should be worked by a pendent rope or chain, but heavier cranes are better operated by men standing on the platform above.

Although hand cranes are open to the objection of being very slow they have the advantage of costing nothing when not in actual service, as compared with steam cranes. For this reason and low first cost they are often better adapted to the requirements of many small workshops, stores and yards than power-driven cranes. Yet electric cranes are far handier and altogether better than hand cranes when employed on frequent service, even if the maximum load does not exceed 5 tons. They soon pay for the additional first cost.

Before the advent of electricity the *steam* Goliath was a valuable machine, and it still has a more limited application. Like the hand crane it has either a crab or a trolley. In the first case the engines and gears are carried on the crab, whereas in the second case they are situated at one end of the beams or bridge.

Steam Goliaths are always operated from above. Apart from this, the general design of the framing is similar to that of the hand Goliaths, whilst the crabs are identical. Pitch chains and sprocket-wheels afford a common method of transmitting power from the engine to the track wheels, an alternative being by means of shafts and bevel gears. A good example of a steam Goliath is depicted on Plate 20, as well as an electric crane.

Electric driving has been extensively applied to Goliaths, as in the parallel case of overhead travelling cranes. Two motors are provided on the crab for hoisting and traversing respectively, also one on the bridge for travelling. The current is taken from suspended wires some distance up the sides of the Goliath, the rolling contacts and other details being similar to those of travellers.

Goliaths with rigid end fixings are unsuitable for spans of over 100 ft. In the Brown cranes the pivoting of the bridge girders to the trestles permits of spans exceeding 200 ft. Such cranes will hoist a full load of, say, 10 tons at rates of from 100 to 300 ft. per min., will trolley or cross-traverse at from 500 to 1200 ft. per min. and will travel at speeds varying from 300 to 900 ft. per min. These cranes are used in steel works and for shipbuilding, being sometimes provided with a cantilever extension at one end.

Although timber has been much used in past years for Goliath framings, steel is far preferable for permanent service and is now generally employed. Steel framings are built up largely of rolled channel sections, braced with angles and flats, and united with gusset plates. The bridge is built from single-web girders in the lighter cranes and from double-web box girders in the heavier cranes, or one may adopt lattice girders.

A Powerful Electric Goliath.—There is a drawing of an unusually heavy Goliath in the crane section of " Kempe's Engineer's Year Book," contributed by John H. Huntley. This interesting electric crane was designed to lift loads up to 200 tons in magnitude at the slow speed of 3 ft. per minute.

The load is lifted on sixteen parts of wire rope, one part winding on to each of two drums, driven through quadruple reduction gearing by a 65-H.P. motor. Lighter loads up to 75 tons are lifted at the rate of 8 ft. a min. by utilizing change-speed gear. The crane is equipped with both solenoid and automatic mechanical brakes, the latter being enclosed in an oil box.

The crab is mounted on four two-wheeled bogies, and is traversed at a speed of 30 ft. a min. by means of a 25-H.P. motor, driving four runners through quadruple reduction gearing. The traversing controller is of the drum type, whereas the hoisting and the travelling controllers are of the contactor type.

The entire crane travels on a twin-rail track. There are eight centre-flanged steel-tyred wheels under each leg, of which four wheels on each side are driven by a 65-H.P. motor, the travelling speed being 50 ft. per min. Fig. 122 shows a centre-flanged wheel, designed for running on twin rails, and in this case driven by a worm and worm-wheel.

All the motions of the crane are operated from an enclosed cabin, placed in an elevated and commanding position. The bridge girders are of the lattice type, stiffened laterally by auxiliary girders and by bracings.

In a modified design of electric Goliath the crab (carrying a driver's cabin below it) runs *between* a pair of girders, instead of on the *top* of them, as indicated in Fig. 123, thus saving head-room. The bridge can be usefully cantilevered at each end, for lifting goods from trucks standing beyond the crane track. In this design the supporting legs are left open or widely separated above the two end carriages and are tied together laterally at the top above the level of the girders, thus permitting a clear run of the crab and suspended load.

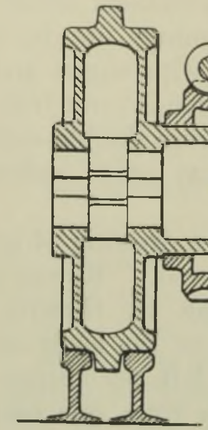


FIG. 122.—Worm-driven Centre-flanged Wheel.

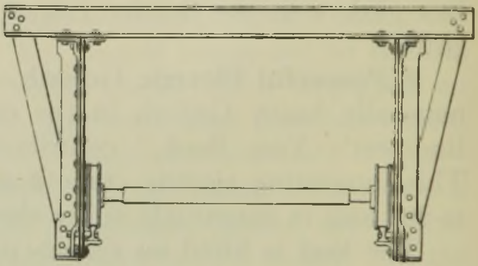


FIG. 123.—Cross-section of Special Goliath Girders.

TITANS

Titans are heavy cranes designed specially for handling and setting big blocks of concrete used in the construction of breakwaters for harbours. They range in lifting capacity from 20 to 100 tons, the majority being built to lift blocks weighing from 30 to 40 tons. Though electricity has been applied to them, Titans are usually driven by steam, one set of engines performing all the lifting and travelling operations, as well as the jib slewing and the trolley traversing motions. Heavy self-moving *crabs*, complete with hoisting gear, are not used on Titans, the position of the simple and relatively light *trolley* being controlled by a wire-rope hauling gear.

The concrete blocks are prepared in a blockyard and transported on trucks, from which they are picked up by the crane and carefully deposited in their final position. As a rule the blocks have to be set down some yards ahead of the main framing carrying the jib. They are either placed quite regularly and bonded together or are arranged at the sea face in irregular formation. The blocks provide the foundation for the track on which the Titan and the block trucks travel. From time to time the crane advances along the breakwater, as it prepares its own track.

It is of historical interest to note that the first example of a Titan crane was constructed in the year 1869 for the harbour works at Karachi in north-western India. It comprised a tall truck running on flanged wheels and carrying a lattice-braced horizontal jib, on which a block carriage, jenny or trolley was racked to and fro over the area of deposition. This early form of Titan, however, had no slewing motion.

In 1881 another block-setting crane was built for the harbour of East London in South Africa, in which the horizontal jib was supported by tie-rods from a king-post and made capable of rotating through a complete circle around the post. This general design of crane was also utilized in the construction of the first Tynemouth Mammoth in the same year. Its capacity was 40 tons at a radius of 95 ft. Rather surprisingly, however, the framing was built up of timber, including both the bottom framing and the jib, as well as the king and the queen posts to which the ironwork was secured.

In the case of a jib supported by tension rods, the rods have to be attached to a king-post above as well as to stirrup anchorages on the jib itself in order to provide clearances for the trolley and the hoisting ropes or chains. But the jib of a tie-rod crane is much lighter than a self-supporting cantilever jib, though the latter can certainly be lattice braced and its members suitably proportioned to withstand the forces coming on them. On the whole the advantage lies with the cantilever jib design.

The jib members are prolonged behind the frames, while all heavy gearing, engines and boiler are concentrated there in order to assist in counterbalancing the loaded jib. Extra balance weight is often provided by a water tank holding several tons of water, in addition to some tons of loose weights or ballast. Thus the crane is made stable under all conditions of working.

In the case of the early Tynemouth Mammoth of 1881, the load was hoisted by steel pitch chains and sprockets, but soon afterwards wire ropes and grooved drums began to be adopted. The travelling gear of a Titan crane still includes pitch chain and sprockets on the axles of the truck wheels, or alternatively shafts and bevel-wheels. Slewing is done from gearing at the rear end of the jib, the first-motion shaft passing down through the centre of the post.

In a modern Titan the truck forms a portal for the passage of concrete blocks. It carries a live ring of conical steel rollers on which freely rotates around a centre pin the superstructure in the shape of two parallel double cantilevers, which are rigidly connected at the nose.

The trolley or jenny runs on rails and carries the top sheaves from which the loaded bottom-block is suspended by steel-wire ropes. Sheaves are provided at the end of the jib for guiding the ropes that pull the trolley along in a horizontal path.

Reeving of Hoist Ropes.—Fig. 124 indicates purely diagrammatically how the hoisting ropes are arranged in a dual system, so designed as to secure central loading in respect of both the hoisting gear and the jib. Each rope leads from the barrel or hoisting drum to the trolley, where it passes over three sheaves and supports half of the total load by four-part suspension, the common bottom-block carrying four sheaves. From the last sheave on the trolley the wire rope is led to the front end of the jib, where it passes around a horizontal guide sheave, then joins up to its fellow on the left-hand cantilever and so back to the hoisting drum *via* the trolley and the block.

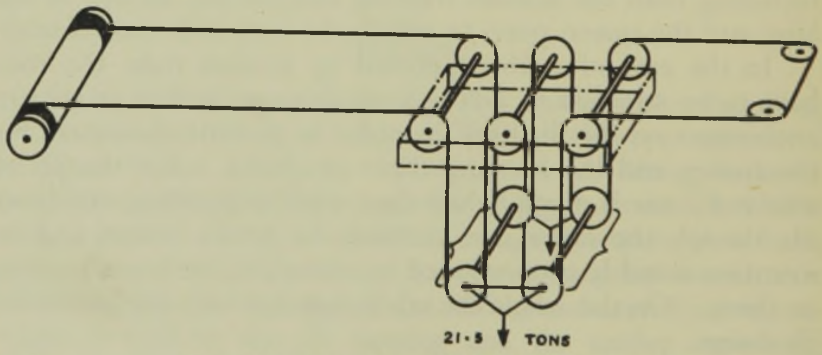


FIG. 124.—Rope Reeving of 40-ton Titan.

The back or rear arms of the jib carry a *machinery* platform and cabin for the crane driver, their ends forming a box to house the ballast weight. This latter is needed to balance the load on the hook and the weight of the forward cantilevers, thus maintaining equilibrium.

Stability is required in all positions of the load and the jib in relation to the truck. This is effected by providing a very wide gauge for the rails, plus a long wheel-base to the truck and a roller path of large diameter for the revolving jib. The wide gauge must be adequate to allow of the laying down of standard gauge rails between the Titan track rails.

When the gauge is very wide the roller path is made about the same diameter as the width of the truck. Otherwise the roller path is carried out or projected over the sides, bringing the centre of gravity of the revolving mass well within the base. The upper roller path or race is bolted to the lower face of a circular girder which in turn is riveted to transverse girders below the jib girders. It is identical in diameter and section with the lower roller path on the truck. Angle brackets further stiffen the connection of the racer to the jib members.

A big Titan crane will weigh upwards of 400 tons, including the ballast. Obviously the problems involved in its successful construction are considerable, arising from the movements of such great masses. When carrying a load of 40 tons, hanging out some 80 ft. beyond the front wheels, it is easy to understand that the enormous load on the rails may be a cause of trouble.

When a load is picked up, the front of the jib drops several inches. To prevent fracture of the track wheels and bending of the rails, it is necessary to fit the axle bearings with volute springs and to distribute the weight of the crane over some sixteen wheels about 3 ft. diameter. These track wheels are made of either cast iron or steel, with rolled-steel tyres turned on the treads. For very heavy work the wheels are commonly made double, with a centre flange. The axle bearings are bolted to the bottom horizontal girders.

The roller race, of 30 to 35 ft. diameter, is made of mild steel segments bolted to the main circular girder by turned bolts. The 12-in. steel rollers are pitched at small intervals Some of the rollers are kept in position by tie-rods from a centre piece, whilst others are simply confined by the roller rings.

The slewing ring is made of about the same diameter as the roller race. It is cast in segments and bolted to the lower circular girder. The lifting drums for wire rope range from 4 to 8 ft. diameter. Their spiral grooves were formerly cast, but are preferably cut or machined in the lathe.

A FINE EXAMPLE OF A TITAN

Some interesting technical data are given by P. A. Arbenz and H. W. Mellor in their instructive paper on "The Structural Design of a 40-ton Titan Crane," presented in 1920 to the Association of Engineering and Shipbuilding Draughtsmen. This paper goes closely into the methods of calculating and designing the structural parts of a typical Titan, comprising the twin cantilevers and the truck or undercarriage, to which reference is made in the following pages. The particular crane considered in detail was designed and constructed at Bath by the firm of Stothert & Pitt Ltd., and was used by a firm of contractors for extending the breakwater at Fishguard, in Wales, where the Great Western Railway Co. have constructed modern harbour works on the Irish Sea. Later it was re-erected on another site at Peterhead in Scotland. This noteworthy crane is depicted in two views on Plate 28.

The strength of the structure demands the most careful attention of the designer in view of the working position of the crane on the breakwater, exposed to gales and heavy seas. Rigidity is also essential to enable this huge machine accurately to set solid concrete blocks, each weighing 40 tons and measuring $12 \times 7 \times 7$ ft., or 588 cub. ft., giving a density of 14·7 cub. ft. to the ton.

The *primary* stresses in the superstructure and the truck depend on the load suspended from the trolley plus their own weight, including the wire ropes and the bottom-block besides the weights of the gearing, all acting vertically. Fig. 125 shows the frame and stress diagrams for this big crane.

The *secondary* stresses in the crane structure are those caused by the horizontal forces due to wind pressure and to the inertia of the parts when slewing, as well as to any internal forces, including those due to the gearing and the system of hoisting ropes, also the tractive resistance of the rails to the motion of the trolley.

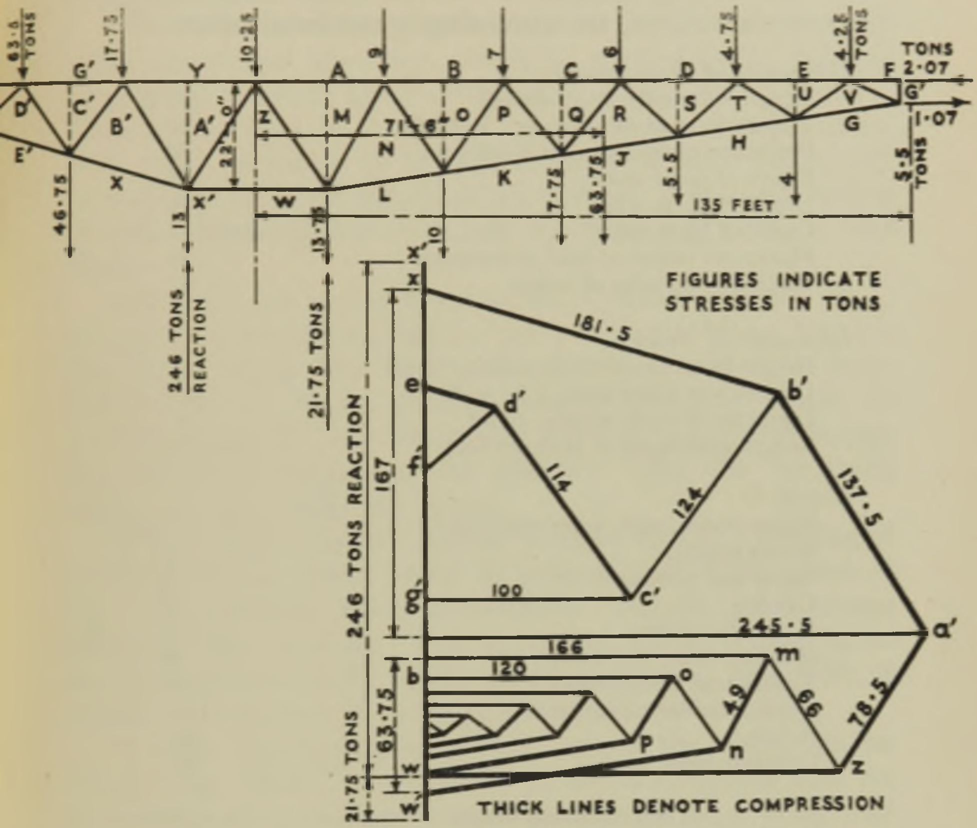


FIG. 125.—Frame and Stress Diagrams of 40-ton Titan Crane.

Speeds, Dimensions and Weights.—The concrete blocks are lifted at a speed of 8·5 ft. per min. and at a maximum radius of 125 ft. from the centre pin. The cantilever makes a complete revolution in 3 minutes.

The trolley carrying the load has eight wheels running on four rails, and its range of traverse is 97 ft. As the rolling load is 50 tons, including the trolley itself, the wheel pressure on one rail is $6\frac{1}{4}$ tons.

The double cantilever with its trolley and machinery weighs 208 tons, thus making the total *revolving* weight of the loaded crane 343 tons, including 95 tons of ballast.

In addition to this, the complete truck or under-carriage weighs 160 tons, making a grand total of 503 tons for the whole crane and its load, or 463 tons without the concrete block.

A few leading dimensions of this Titan crane, along with the various weights, are conveniently tabulated below :—

Dimensions of Superstructure.	
Length of cantilever jib overall	195 ft.
Projection of front arms, in 5 full bays	135 ,,
Projection of rear arm, in 2 full bays	60 ,,
Depth of jib at centre	23 ,,
Depth of jib at rear	10 ,,
Depth of jib at front	about 6 ,,
Maximum radius of load or outreach	125 ,,
Maximum traverse of trolley	97 ,,
Dimensions of Truck.	
Height to centre of 12-in. rollers, 56 off	21½ ft.
Diameter of roller path, 7 in. wide	31 ,,
Diameter of truck wheels, 16 off	3 ,,
Length and depth of main girders	38×5½ ,,
Weights.	
Steam boiler, with water and coal	10 tons
Steam engine	3 ,,
Cabin and platform	12½ ,,
Gearing	6½ ,,
Hydraulic brakes	5½ ,,
Hoisting drum and wheels	9½ ,,
Trolley and snatch-block 7 + 3	10 ,,
Double-cantilever structure	151 ,,
Ballast	95 ,,
Concrete block load	40 ,,
Total revolving weight	343 tons
Truck structure	125 ,,
Truck wheels, axles and gearing	35 ,,
Total moving weight	503 tons

Thus the entire crane in working order, but without its 40-ton load of concrete, weighs 463 tons.

General Remarks on Crane Comparisons.—Although this titanic crane is not a particularly big one so far as the magnitude of the effective load lifted is concerned, yet it is certainly a very heavy one as regards its own weight. This is accounted for by the fact that the load is lifted at the long radius or outreach of 125 ft., thus producing the very great tipping moment of 40 tons × 125 ft. or 5000 ton-ft. This necessitates substantial steel sections and a very heavy counterweight or ballast, so that the total load on the truck rails amounts to the enormous figure of 503 tons, which is $12\frac{1}{2}$ times the effective load.

Obviously, in order to gain a correct idea of the size of a crane one should know not merely its vertical lifting capacity but also its *moment*, when comparing one crane with another. Thus in the case of a modern 10-ton steam shunting crane with a jib radius of 16 ft., the moment is only 160 ton-ft. In this case the total weight of the crane is 48 tons (including 10 tons of ballast), which is only 4·8 times the effective load lifted.

Normally one would say that an overhead traveller lifting 60 tons on the hook is a heavier crane than one lifting 30 tons. But if the former had a span of only 30 ft. whilst the latter had a span of 70 ft., their respective moments would be $\frac{1}{4} \times 60 \times 30$ and $\frac{1}{4} \times 30 \times 70$, or 450 and 525 ton-ft., neglecting the structural weights of the cranes. Thus the nominally heavier crane is really the lighter.

It is of mathematical interest to note that the weights of precisely *similar* cranes would be proportional to the cubes of any corresponding linear dimensions. Similar here means differing only in scale. But of course actual cranes never *are* made geometrically similar in every respect, especially as regards the *thickness* of castings, plates and steel sections.

A rough approximation to the *cost* of the above 40-ton Titan crane would be £20,000, on the assumption that we have 368 tons of machinery and structure at an average cost of £50 a ton and 95 tons of ballast at £5 a ton or less. On the same basis the above 10-ton shunting crane would cost (38 × £50) + (10 × £5) or £1950, which is not far out.

FLOATING OR PONTOON CRANES

While on the attractive subject of crane comparisons and costs we may here briefly refer to a 150-ton floating crane, known as the ‘ London Mammoth,’ which was built in the year 1927 for the Port of London Authority at a cost of £80,000, as stated in Asa Binns’ instructive paper.[1]

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[1] “ Recent Developments in the Mechanical Equipment of the Port of London Authority,” *Proc. Inst. of Mech. Engineers*, 1932. Mr Binns was then Chief Engineer to the Port Authority.

This crane is outlined in Fig. 126, which also shows to the same scale the 50-ton floating crane ‘Hercules,’ built in 1903 for the same port. The cost stated includes a pontoon 200 ft. long by 77½ ft. beam by 14 ft. deep, which is propelled at about 5 knots by twin screws. Steam at a pressure of 150 lb. per sq. in. is supplied by a coal-fired marine boiler. The crane is operated electrically, current for the motors being generated by a steam-driven dynamo.

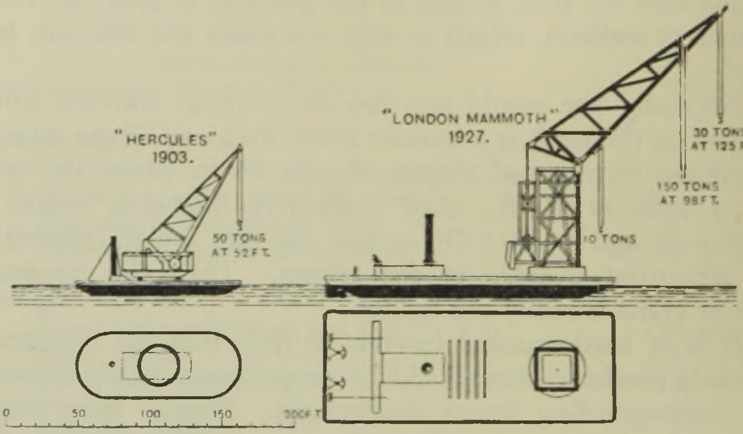


Fig. 126.—Two Floating Cranes on the Thames.

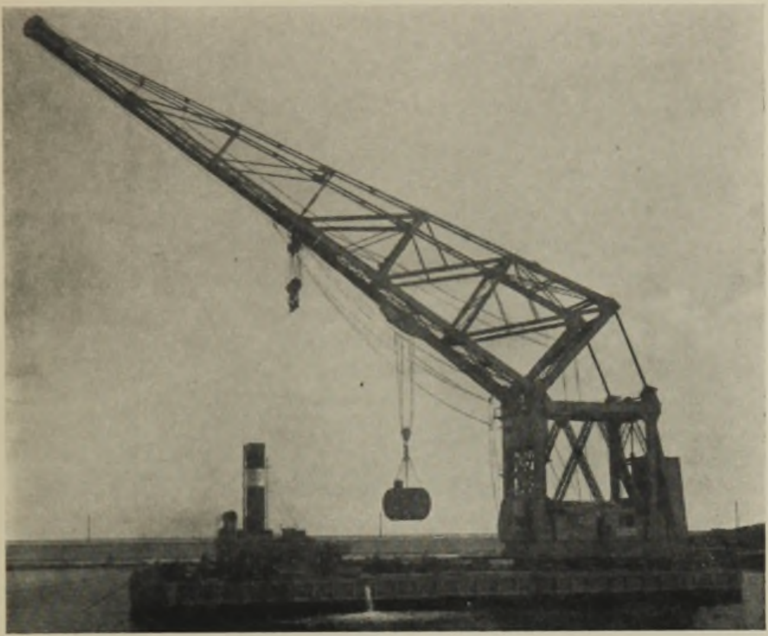
Some particulars of the ‘London Mammoth’ and speeds of various operations are given below :—

Main lifting speed	150 tons at 5 ft. a min.
	or 75 tons at 10 ft. a min.
Lifting speed on auxiliary	30 tons at 20 ft. a min.
	or 15 tons at 40 ft. a min.
Lifting speed on auxiliary trolley when traversing	10 tons at 40 ft. a min.
Slewing (one complete revolution)	150 tons in 6 min.
Total height above water at minimum radius	220 ft.
Height of 30-ton hook above water	150 ,,
Height of 150-ton hook above water	130 ,,
Maximum radius of 30-ton hook	125 ,,
Maximum radius of 150-ton hook	98 ,,
Minimum radius	60 ,,

Thus the greatest tipping moment of this Mammoth is 150 tons × 98 ft. = 14,700 ton-ft., as compared with 5000 ton-ft. in the case of the 40-ton Titan we have been considering.

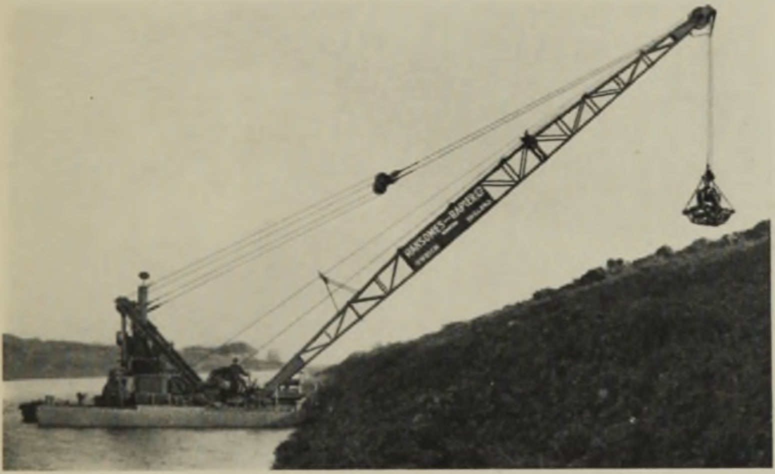
As Asa Binns remarks, it is interesting to note that during a period of two years, ending in March 1931, this crane carried

PLATE 27



Cowans, Sheldon & Co. Ltd., Carlisle.

150-TON FLOATING JIB CRANE.



Ransomes & Rapier Ltd., Ipswich.

STEAM GRAB DREDGER ON PONTOON.

[*To face page* 192.

Stothert & Pitt Ltd.

Two Views of 40-ton Titan Crane.

To face page 193.]

out 1152 lifts, of which only 4·5 per cent. exceeded 50 tons in weight. Yet one must bear in mind that its superior height and long radius often necessitate its use for relatively light loads, especially in connection with the bigger ships.

Salvage Lighters.—It is noteworthy that the Port of London Authority make use of salvage lighters for raising wrecks and occasionally for removing lock gates. Only one of the seven lighters owned is self-propelled, but all are fitted with powerful steam-driven *winches* and salvage pumps. The largest salvage lighter is capable of lifting 400 tons by utilizing the rise of the tide. All the very heavy lifts are done in this way, two or more lighters being harnessed together when necessary.

The Biggest Floating Crane.—Although the 'London Mammoth' is really a gigantic crane, it is not actually the biggest pontoon crane ever made, being surpassed by a huge crane (illustrated in "Kempe's Engineer's Year Book") made for service in Japan by Cowans, Sheldon & Co. Ltd., of Carlisle. This 'Jumbo' of cranes is designed to lift 350 tons at a radius of 100 ft., 300 tons at 121 ft. or 50 tons at 160 ft. radius, corresponding to *moments* of 35,000, 36,300 and 8000 ton-ft. respectively. The range of *lift* is 140 ft. with the full load and 200 ft. with a 50-ton load. The overall height with the jib raised is 240 ft. above the water-line. A 50-ton trolley runs on the bottom member of the jib.

Luffing of the jib is done by two massive screws fitted with nuts guided in cross heads and connected by long jib links to the upper boom. The lower boom is pivoted to the supporting framing at a height of 60 ft. above the deck. The operator's cabin is placed just below the fulcrum of the jib.

Many floating cranes are *steam*-driven, as in the present case; yet of recent years some large floating cranes have been electrically driven,[1] perhaps at needless expense. A possible alternative to a steam-dynamo drive is a Diesel-electric drive, where an oil engine is coupled direct to a dynamo supplying current to several electric motors.

This 350-ton steam crane for Japan, however, has nine sets of two-cylinder condensing engines, each motion being independently operated without the use of clutches. Hydraulic

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[1] For example, *The Engineer* of April 15th, 1938, describes a 100-ton electric pontoon crane.

brakes are fitted in order to secure exact control of the load during lowering operations.

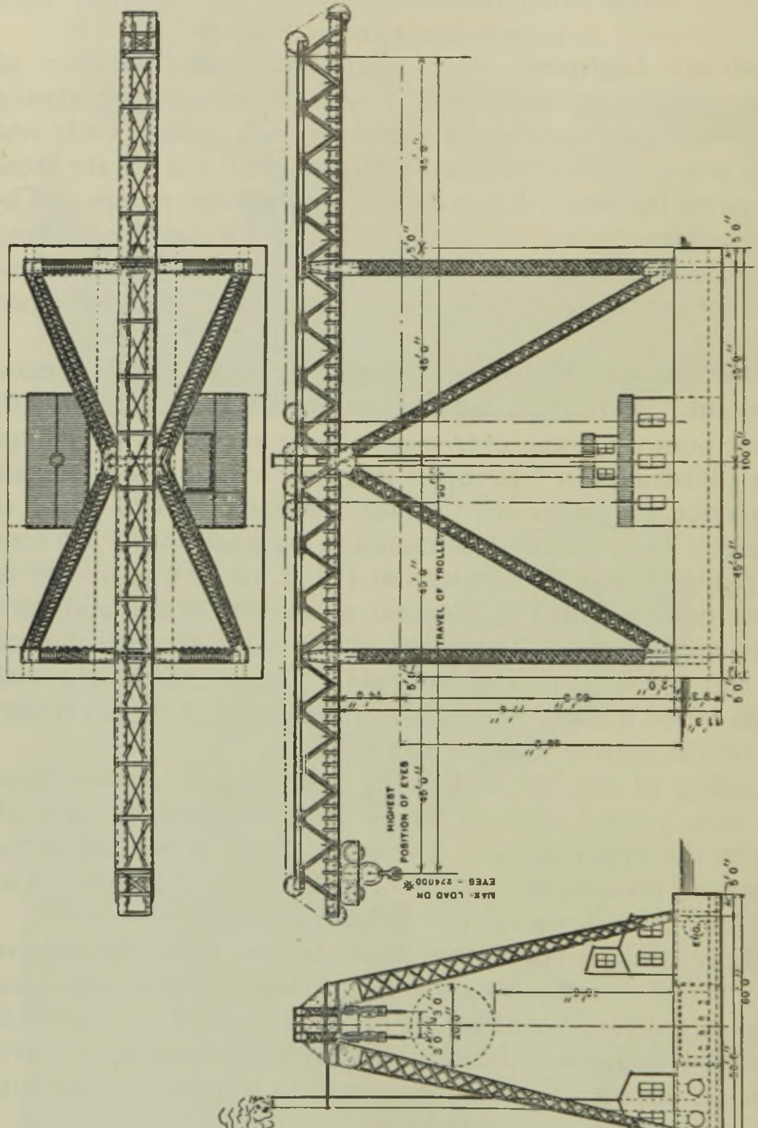


FIG. 127.—100-ton American Floating Cantilever Crane.

The pontoon for this particular crane is 270 ft. long by 91 ft. beam, with a draft of 10 ft. Its propelling machinery consists of twin-screw compound engines, fed with steam at a pressure of 150 lb. per sq. in. from two water-tube boilers. These also supply steam to nine crane engines, to an electric light engine and to the auxiliary machinery.

Pontoons in general are rectangular, flat-bottomed vessels, and they may be either towed or self-propelled. In the latter case it is probably best to give them a ship shape. Under full-load conditions and a wind pressure of 5 lb. per sq. ft., the angle of keel should not exceed 5°. Sometimes travelling ballast is provided in order to limit the keel under various loading conditions.

Floating cranes are mostly used for fitting out and repair service, also for handling dock gates and parts of swing-bridges. The ease with which they can be moved from dock to dock, via a river, gives them perfect mobility and greatly increases their general utility. But it is not easy to deposit a heavy load with precision by means of a floating crane ; for such a crane is affected by the movement of the surrounding water, and its steadiness is disturbed slightly with every fluctuation of loading.

100-ton Floating Cantilever Crane.—An American example of an unusual type of floating crane is outlined in Fig. 127 in plan view and two elevations. This ' Hercules ' was built in 1901, for the United States Navy, by The Brown Hoisting Machinery Co., then of Cleveland, Ohio. It weighs about 1200 tons.

The load suspended from the trolley passes freely between the legs supporting the rigid cantilever arms, its extreme travel being 190 ft. Thus a load can be deposited on the deck of the crane pontoon, or on a separate pontoon moored under either projecting arm.

In addition to the usual water-ballast this pontoon has an automatic counterweight of 250 tons travelling centrally. This weight is operated by an independent pair of engines in such a way as to keep the pontoon on an even keel at all times.

The engines, boilers and pumps are erected in the pontoon amidships, on each side of the counterweight path. The operator's cabin is placed above the engines at a height sufficient to command a clear view of the hook in every position.

NOTE.—A 40-ton Titan crane for East London Harbour, South Africa, is described in *Engineering* of October 3rd, 1913.

CHAPTER XV

GIANT CANTILEVER CRANES

CLOSELY allied to the Titan form of crane is the so-called hammer-head or Giant cantilever crane, yet the latter is always made higher than the former and of much greater lifting capacity. Moreover the Giants are always *fixed* cranes, being never mounted on wheels.

Though it is feasible and necessary for harbour work to mount a 40-ton Titan on a movable truck, it is neither feasible nor necessary to mount a 250-ton Giant on wheels for fitting out battleships and big liners. It is so much easier to mount a gigantic crane on a floating pontoon than on a wheeled truck and thereby gain a maximum of mobility.

A Giant provides a suitable means of lifting gun turrets, boilers and engines, either bodily or in large sections, on board ships being fitted out at shipyards and naval bases should a big floating crane not be available.

There are not a large number of Giant cranes in existence throughout the whole world. The construction of a new Giant is a fine piece of engineering work which is not often repeated. The birth of a Giant is probably a rarer event than the launch of a big Atlantic liner. Also, a Giant has a long life. It does not wear out or become obsolescent in a matter of a quarter of a century, as a liner does. Consequently the construction of Giant cranes is never likely to become a regular routine business but will doubtless remain the exceptional or occasional job of a very few firms possessing a suitable works organization and equipment. In some cases two firms collaborate, one doing the structure and the other the machinery.

On Plate 29 is pictured *a striking example* of a Giant crane, made by Sir William Arrol & Co. Ltd., where a 20-ton auxiliary portal crane travels from end to end of the main cantilever jib. This forms a very convenient feature, as the small crane is always available for overhauling the machinery of the big crane.

This notable crane was tested with a load of 300 tons. The total length of the jib is 318 ft., the front arm being 198 ft. long and the rear arm 120 ft. The height of the tower is 151 ft., while 191 ft. is the height of the rails on the cantilever above the quay level. The base of the tower is not less than 50 ft. square. The tipping moments corresponding to two working loads on the hook are 26,200 ton-ft. for 250 tons at 105 ft. radius and 18,400 ton-ft. for 100 tons acting at an arm of 100 ft.

The subject of " Hammer-head or Giant Cranes " was dealt with by Joseph Horner in an interesting contribution to Cassier's *Engineering Monthly* of April 1914, parts of which are paraphrased in the following remarks.

The German hammer-head crane is an obvious development of the English block-setting Titan crane. Excepting its much greater height and the fact that it is fixed instead of portable, the hammer-head crane is a Titan crane. The horizontal counterbalanced cantilever jib, revolving on a live ring of rollers and traversed by a loaded trolley, actuated by ropes from a source of power at the rear of the jib, were features embodied in the Titans of twenty years earlier, though the motive power of the latter was always steam, whereas the hammer-head cranes were usually operated electrically.

The fixed design of the Giant crane and its greater height and range of lift follow naturally from the different nature of its duties, which consist chiefly of handling heavy engine parts, boilers, etc., for fitting out ships. Here great height is essential while portability is not, because the long jib covers in its rotation a radius of up to 150 ft. and the racking of the trolley permits of bringing the load inwards close to the tower.

The Titan crane is made portable because it must travel out along the wall which it builds, depositing 40-ton concrete blocks at the scar end until the entire length of the sea-wall, pier or breakwater has been built out into the sea. And though the loads which a Titan carries are usually far less than those of a Giant, yet they are so great that they approach the limit for which travelling jib cranes can be built to work satisfactorily. The total weight of the load and the crane itself becomes so huge that the stresses on the wheels and the rails are extremely severe.

The elements of a Giant or hammer-head crane are the tower and central pivot, the roller path and its guides, the trolley and its operating machinery, and lastly the *foundations* on which the whole structure is carried. The entire weight of, say, 300 tons or more must be carried by the quay wall on a foundation which will neither become crushed by the crane nor lifted by the overhanging load. The vast dimensions of these Giants, and the high technical knowledge and wide experience required for their design and construction, ensure their retention as a speciality in the hands of a very few builders. Only those who have ample yard space and powerful plant can undertake their construction.

The Supporting Tower.—The tower has to carry the rotating jib without perceptible vibration or any suspicion of buckling. For reasons of cost it is desirable that the material in so massive a steel structure should not be wasted. The outline which has been evolved is that of vertical members disposed in the form of either a triangle or a square in plan. Many of the earlier German cranes were made triangular, whereas in England the square design is adopted. In the former the spread of the legs is greater, and plenty of room is left between the legs to permit of the movement of trucks.

The large area covered by the tower provides for the stability of the structure, whose individual members are relatively light. The vertical legs are braced both horizontally and diagonally, so that the individual panels are kept short to prevent buckling. The fibre stress allowed on the steel is the same as in bridge and girder work generally, namely a maximum of 6½ tons per sq. in. of net section, both in tension and in compression, while the shearing strength of the rivets is taken at 5 tons per sq. in.

The material used is acid open-hearth steel having a tensile strength of 28 to 32 tons per sq. in., with an elongation of at least 20 per cent. in a length of 8 in. Risk of corrosion is guarded against by leaving all box sections open on one side for the admission of air and by allowing free access to all parts for painting from time to time. Scantlings thinner than ⅜ in. thick are not used either in plates or in rolled sections.

While the bracings of the towers are lattice girders the main vertical members or legs are solid plated, the section being either rectangular or composed of two open-sided box girders set at right angles to each other. The box plating ensures the stiffness needed to resist compression, while the precaution of leaving one side open affords access to the interior for painting and also prevents the lodgment of water, the presence of which is apt to cause corrosion.

At intervals the plated work is riveted to diaphragms by bent tees or angles, forming suitable attachments to the bracings. Thus is a strong and rigid structure secured with the least waste of material. Square towers are usually tapered slightly, there being perhaps 5 ft. difference in the measurements taken at the base and at the top. Attached to three sides of the tower is the staircase by means of which the crane operator ascends to his elevated platform.

The Roller Path.—The crane superstructure turns on a pivot which is either a short one at the top of the tower or one long enough to extend to a footstep on the ground, as seen in the 100-ton crane at Dublin harbour and in the early German designs with the triangular tower.

The roller path and its girders and the central pivot have to carry the entire weight of the cantilever jib, balanced and rotating with its loads. Under the most severe conditions of loading it is necessary to have the centre of gravity well within the roller path by some 5 ft. As an extra precaution safety hooks are sometimes included, to hold to a flange on the slewing rack in an emergency. These hooks fulfil a similar function to the blocking girders and the rail clips so often used with portable balance cranes, but they travel with the rotating superstructure, and only come into action in the event of a sudden surge of the load occurring.

Roller paths range in diameter from 30 to 50 ft., the measurement being taken to the centres of the rollers. These are *live* rollers, that is to say, they are not keyed on rotating shafts but they turn freely on radial rods which are fixed at one end to a central girder and at the other end to a light ring of channel section. The rollers are tapered slightly, the apex of the cone coinciding with the centre of the pivot around which the superstructure revolves.

When the cantilever is revolved it rotates the rollers, which run between top and bottom *races* or annular tracks of a section according with the taper of the rollers. The other faces of the races are bolted against the flat faces of the annular or circular girders on the tower and the cantilever respectively. These races are made of either cast or forged steel.

To the lower race is bolted a circular gear or slewing rack, either cast in segments or formed of steel pins, with which gears the pinion whose operation rotates the cantilever jib.

The races are bolted to a system of top and bottom box-plated girders, one being attached to the bottom of the jib and the other to the top of the tower. Both of these girders may be in the form of rings.

Alternatively the girders in the tower are composed of deep box girders, comprising four main ones in rectangular formation, attached to the legs of the tower, and four short diagonals ; the whole system thus affording an octagonal bedding for the support of the lower race or roller path.

The upper girder to which the top race is bolted is also circular and of box section, being attached to the bottom of the jib. Additional girders crossing the centre of the upper and lower races receive the bosses through which the centre pin passes, around which pin the jib revolves.

All this structural work is plated and designed of ample proportions to enable it to resist not only the pressure of the immense jib but also to prevent the risk on any part springing at the time of lifting full loads. A very slight spring in these parts would produce unequal pressures on the rollers and their paths, or even throw some of the rollers out of action and thus increase the load on the others.

The Jib.—The cantilever jib consists of two main girders, each lattice braced, connected by cross girders and bracing members, and provided with rails for the travelling trolley from which the load is suspended. It is pivoted on top of the tower by a central pin and it carries the upper racer or roller path.

The jib comprises a long arm, along which at various radii the lifting takes place, and a shorter arm which affords the necessary counterpose partly by its own weight. Most of the counterbalance, however, is effected by concentrating on the shorter arm all the operating machinery as well as many tons of ballast, the amount of which is estimated to counterbalance the biggest load on the hook at the longest radius it is ever lifted.

The problems met in designing a suitable jib are rather complicated. Though the counterbalancing itself is not difficult, yet it is a fixed amount to set against loads of variable magnitude and moment. Surging is liable to occur when a heavy load is suddenly either dropped or lifted. Some other matters which can only be fully appreciated when a crane is either under test or in actual service include the deflection of the jib and its *lateral* stability when slewing, also the ability of the rails and the top booms to sustain the maximum loads lifted without perceptible yielding.

Exposed as these Giant cranes are to strong winds, the lattice type of girder is imperative to reduce the exposed area. A wind pressure of 50 lb. per sq. ft. is usually assumed. An area equal to 1½ times that presented by the elevation of the crane is regarded as being subject to wind pressure, the assumption being that the pressure on the leeward side is equal to one-half of the pressure on the windward side. The top booms of the cantilever jib are adequately supported by introducing vertical members to shorten the unsupported length between the joints.

All the operating mechanism is located at the rear of the shorter arm, where it is suitably housed. This machinery, along with the weight of the rear arm itself plus the ' Kentledge ' or ballast, forms the counterbalance of the load. Communication with the moving trolley is made by means of wire ropes connected to the front end of the jib.

Lateral stability of the cantilever jib is ensured by making each member double, in box-girder fashion, and connected with plating above and by lattice bracing between the sets of diagonals and verticals. Also the extreme ends of the longer arms are united by a lattice girder.

The space between the girders is left clear as far as the front of the roller path, in order to permit of racking the suspended load along the trolley rails. Beyond that point, up to the back end, the cantilever girders are connected by diagonal bracings.

The circular girder to which the top race is bolted is secured to the main girders by raking struts, one on each side of the centre. A staircase extends from the top of the tower to the top of the jib, giving access to the operator's cabin.

When the load lifted is very great, such as 250 tons, the heavy loads on the wheels of the trolley are apt to cause bending of the rails and of the top booms. Precautions have to be taken to prevent this bending. These local loads are additional to the bending stresses imposed on the cantilever jib as a whole.

Problems of a similar kind occur in the block-setting Titan cranes. In some of the early examples of these the rails became bent and the wheels fractured. This was later prevented by the adoption of double rails and central flanged wheels, and by the addition of stiff springs fitted to the axle boxes. In the Titans, however, the loads carried are only about a quarter of those handled by the Giants, while the radius is shorter and the height of lift only about a third.

The Machinery and Drums.—The trolley and its operating gear are always driven electrically in hammer-head cranes. There are separate mechanisms for lifting the maximum and the smaller loads and also for racking the trolley along the jib. Electric power being available, each motion of the crane is independent of the others. In a heavy crane there are three wire-rope drives, each having its own motor, though two motors are used for the biggest lifts. Each motor drives through reduction gears, the lifting gears being equipped with both magnetic and mechanical brakes.

In the general arrangement or layout the heaviest portions of the machinery are placed nearest to the tail-end of the cantilever jib. First comes the lifting drum, whose diameter may be as much as 10 ft. It is grooved with both a right-handed and a left-handed spiral, around which the two wire ropes are wound simultaneously. The ropes are anchored to the drum at one end and to brackets on the front of the jib at the other end. Between these points the ropes pass over sheaves on the trolley and around a bottom-block suspended in the bight of the rope, the number of falls of rope being suitably proportioned to the greatest load to be lifted.

As the range of lift is so great, possibly reaching 170 ft., the drum must be of large diameter to accommodate the ropes.

Moreover it has a large number of grooves, because only a single bight of rope is permitted to lie in a groove, to prevent over-riding and dangerous surging when under heavy loads.

In front of the drum are placed the electric motors which drive the main spur-wheels, one at each end of the drum, through intermediate reducing gears. These gears have cut teeth and they run in oil. The main spur-wheels are not keyed on the drum shaft but on the drum itself, the torque being therefore transmitted direct to the drum. The magnetic and mechanical brakes are both fitted to the intermediate shaft.

The drum for lifting the lighter loads is driven by a single motor through spur reduction gears to a large spur-wheel keyed on one end of the drum, also equipped with a magnetic brake. The wire ropes are anchored at one end to the drum and at the other end to brackets at the front of the jib. The bottom-block hangs from a second set of sheaves on the same trolley that handles the heaviest loads. This light drum is only about half the size of the main drum and it revolves about twice as fast or more.

Forward of this lighter lifting drum is the still smaller racking drum with a double spiral groove, which is driven by a motor through reducing gears, and is fitted with a magnetic brake. The sole function of this drum is to haul the trolley along with its suspended load, which it does at two speeds. The trolley is a low truck running on central-flanged wheels for double-rail tracks, and carrying the guide pulleys or sheaves on which the wire ropes move and carry the bottom-blocks in their bights.

In the case of some early examples of both Titan and Giant cranes, instead of a trolley hauled along by a rope there was fitted a self-propelling winch or crab, as usually adopted in overhead travelling cranes. But the crab was long ago abandoned in favour of the simple trolley, which is much lighter.

A heavy crab renders necessary a somewhat stronger construction of the jib. The weight of drums, motors and gearing, as well as larger and heavier frames, has then to be carried on a cantilever instead of on a beam supported at both ends, which is an important difference from overhead traveller construction. Moreover, whatever additional load is imposed on the end of a cantilever jib has to be counterbalanced by more weight on the rear arm, thus increasing the load on the roller path and also rendering sudden jerks and surges more severe and trying to the crane structure.

The slewing or rotating of the jib is effected by a separate motor and gearing, usually placed over the centre of the tower between the cantilever girders. The high speed of the motor is reduced by worm gears and transmitted by spurs and bevels to the pinion that engages with the teeth of the slewing ring, which are of coarse pitch, namely from 5 to 6 in. circular pitch. Pin teeth, however, are often used in preference to ordinary teeth, whether cycloidal or involute. In that case each tooth is simply a turned steel pin secured in rings, while the pinion is of forged steel with machine-cut teeth.

Crane Foundations.—The foundation for an ordinary fixed crane of moderate size is a monolithic mass of concrete in which the bolts are embedded. The bolt heads take their pull on large washer plates, the nuts being tightened on the feet or lugs of the baseplate. In a Giant crane, however, the legs of the tower are placed so far apart, perhaps 50 ft., that the usual practice is to sink a separate foundation under each leg.

Caisson-like steel cylinders are sunk, the ground within is excavated and the space is filled with concrete, into which the holding-down bolts are secured. The cylinders may be 9 or 10 ft. diameter and some 10 ft. deep, bell-mouthed at the bottom in order to lessen the load on the ground by the distribution of the concrete. The pressure on the base is not allowed to exceed 10 tons per sq. ft. when the crane is fully loaded. In the case of the 150-ton Clydebank crane the foundation cylinders are no less than 70 ft. deep and 10½ ft. diameter.

Examples of Giant Cranes.—Two more examples of hammer-head cranes may be fitly referred to, one being erected on the Clyde and the other in Japan. In the case of the 150-ton crane at the fitting out basin of John Brown & Co. Ltd., Clydebank, Glasgow, the cantilever jib is 240 ft. in total length, while the long arm on which runs the load trolley projects 150 ft. from the centre of the square tower, measuring 40 ft. at the base and tapering to 35 ft. at the top, suitably braced horizontally and diagonally.

The jib is carried on a roller path 35 ft. diameter, having 75 solid forged-steel rollers, each of 14-in. mean diameter and 14 in. long. Hollow cast-steel rollers were ruled out as too risky. The type of girder adopted for the cantilevers is the Warren, with the addition of intermediate verticals, which are inserted to break up the panels of the top boom into smaller bays; thus enabling them to resist the bending stresses due to the enormous wheel pressures imposed on the trolley by maximum loads.

The various speeds of this successful crane are tabulated below :—

Motion	Load	Speed
	Tons	Ft. per Min.
Maximum lift . .	150	5
Do. . .	100	7·5
Auxiliary lift . .	30	12·5
Do. . .	7·5	50
Racking . . .	150	40
Do. . . .	30	100
Slewing . . .	150	10 min. per turn
Do. . . .	30	5 " "

Now we come to the second example. This is a very powerful crane built by Cowans, Sheldon & Co. Ltd., of Carlisle, to the order of the Imperial Japanese Navy for the Kure Dockyard. Its greatest working load is 200 tons, though tested to 250 tons, at a maximum radius of 105 ft.

The vertical tower is parallel from top to bottom and measures 50 ft. square between the centres of the main columns, which are 2 ft. 9 in. square. These columns are provided with grillage soleplates and are embedded in solid concrete down to a depth of 10 ft. 6 in. below the quay level. Steel stairways are carried up to the top platform.

The lattice-braced tower stands 109 ft. high above the quay. It carries girders 20 ft. deep which support the lower roller path in conjunction with the cross girders. The roller paths are 50 ft. diameter on circular girders 2 ft. 6 in. deep. Ninety forged-steel rollers, each 12 in. diameter, carry the revolving superstructure, rotating around a steel pin 18 in. diameter.

The jib cantilevers are 270 ft. long by 34 ft. deep at the centre. They are fixed at 20-ft. centres apart and suitably braced at front and back. The trolley rail tracks on the top flanges are double and set at 4-ft. centres.

The slewing gear is duplicated and comprises worm, spur and bevel gearing along with a slipping device. The big slewing ring is of the pin-gear type, and its pinion is of forged steel. Two slewing motors are installed, each of 60 H.P., running at 550 turns per min. These motors and gears are enclosed in a house placed centrally over the tower, whereas all the other operating gears are grouped in a house or cabin at the tail-end of the cantilever. They comprise the main and the auxiliary lifting gears, also the racking or trolley traversing motion. The latter is operated by a motor of 30 H.P., which is capable of traversing a load of 200 tons at a speed of 30 ft. per min. and 100 tons at 60 ft. per minute.

Two motors, each of 60 H.P., are provided for the main lift of 200 tons in two blocks at a speed of 5 ft. per min., the motors running at 550 revs. per min. When using one bottom-block only a load of 100 tons can be lifted on a steel-wire rope of $5\frac{1}{2}$ in. circumference.

Loads up to 15 tons are lifted at 25 ft. per min. The light auxiliary hook of 30 tons can be hoisted at 20 ft. per min. at the long radius of 160 ft. and loads up to $7\frac{1}{2}$ tons at 50 ft. per min. For this auxiliary lift a motor of 60 H.P. is provided, the ropes measuring only $4\frac{1}{4}$ in. circumference.

A most useful addition is an overhead travelling crane placed over the machinery at the tail-end of the jib for handling the gears and other details. It is driven by a 10-H.P. motor and is capable of lifting one main drum, complete with its spur-wheel and shaft, weighing 15 tons.

The enclosed motors are all series wound for working on direct current at 220 volts. The rating provides for a rise of temperature not exceeding 70° F. after a run of one hour on full load. Tramway type controllers are used. On the switchboard in the operator's cabin there are switches, circuit breakers and fuses for each motor circuit, besides a main switch and circuit breaker. The lighting circuits are also controlled from the board.

The numerous safeguards and conveniences fitted to this Giant crane include electrical and mechanical brakes, an alarm bell and an indicator to give warning of overloading, also a dial radius indicator to enable the operator to see the permissible loads and radii, and, finally, a telephone in the cabin to enable him to communicate with the machinery house.

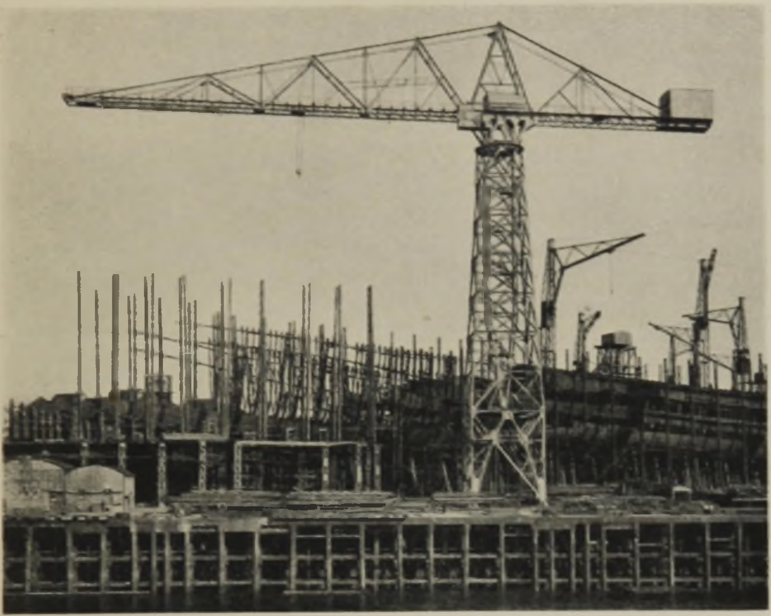
CHAPTER XVI

SHIPBUILDING CRANES

WHEN sailing down the Clyde past the many famous shipyards that line its banks, one is impressed by the numerous tall structures towering above the shipbuilding berths, for the purpose of transferring material from the yards to the hulls in course of construction. Prominent amongst these structures are the so-called *tower cranes*, which serve the heaviest berths, including those reserved for the biggest Atlantic liners and battleships.

These shipbuilding cranes with their high cantilever jibs contrast vividly with the groups of light quay cranes, having long luffing jibs, which are so striking a feature of the skyline in the neighbourhood of the docks in the Port of London. For the most part the Clyde cranes are designed to handle parts of ships, whereas the dockland cranes on the Thames are mostly intended to handle cargo. This clear difference of function is fully reflected in designs of totally different appearance and capacity.

Tower Cranes.—The cost of shipbuilding is largely influenced by the expeditious handling of steel plates and sections at the building berths, for which duty the cantilever tower crane has proved to be a most efficient machine. Both fixed and travelling tower cranes have been made, but British practice favours the fixed type, as diagrammed in Figs. 128 and 129, whereas the travelling type has been extensively adopted by the German and other Continental shipyards. A point in favour of *fixed* cranes is that they need less clearance between the berths than their rivals. Thus valuable space can be utilized that would otherwise have to be kept clear for the track of a travelling crane. The tower cranes for service at building berths are usually made of 5 tons capacity at 100 ft. radius or 10 tons at half that radius, equal to a moment of 500 ton-ft.



Sir William Arrol & Co. Ltd., Glasgow.

10-TON FIXED TOWER CRANE FOR SHIPBUILDING.

Sir William Arrol & Co. Ltd., Glasgow.

250-TON GIANT CRANE FOR FITTING OUT SHIPS.

[*To face page* 208.

Sir William Arrol & Co. Ltd.

25-TON FITTING-OUT CRANE WITH CRUISER.

Sir William Arrol & Co. Ltd.

10-TON LEVEL-LUFFING CRANE LIFTING TIMBER.

The crane structure consists of a balanced double cantilever supporting the track for the load trolley, and is carried on the top of a braced steel mast, the whole being free to revolve inside a high tower. The mast inside is carried at the bottom by a footstep bearing, and the upper end of the mast is supported by roller bearings at the top of the tower. A series of tie-rods connect the cantilever jib to the top of the mast. Enclosed in a cabin at the rear of the jib is the machinery for hoisting the load, slewing the crane and racking the trolley along the jib, each motion being operated by a separate motor.

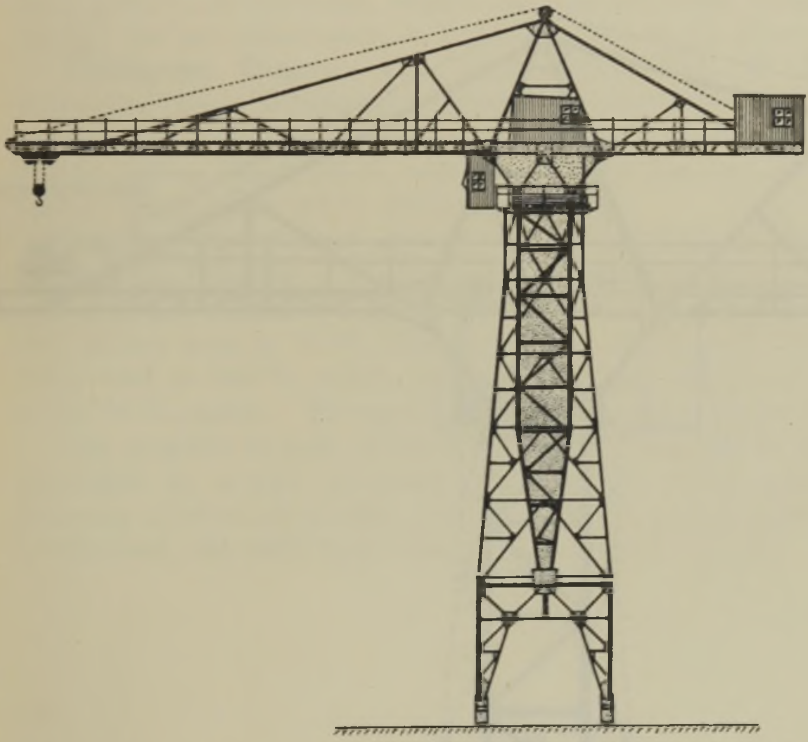


Fig. 128.—Cantilever Tower Crane.

A special feature of the best tower cranes, as made by Sir William Arrol & Co. Ltd., is the duplex electric control. This enables such cranes to be operated either from the driver's cabin, suspended from the underside of the cantilever jib, or by means of portable controllers which may be placed at ground level or on the deck of the ship under construction. These cranes are fitted with an automatic device to prevent the safe load for its radius being exceeded, which limits the traverse of the trolley for a given load.

Plate 29 pictures a 10-ton fixed electric tower crane, designed by Sir William Arrol & Co. Ltd., to facilitate the construction of the world's largest liners at the shipbuilding yard of John Brown & Co. Ltd. on the Clyde. This fine example will lift 10-ton loads at a radius of 160 ft. to a height of 145 ft. above the quay level, the moment thus being 1600 ton-ft. The base of the crane was so constructed that after the completion of the ship's hull the crane could be skidded over to the side of the wet basin and there further utilized for fitting-out purposes.

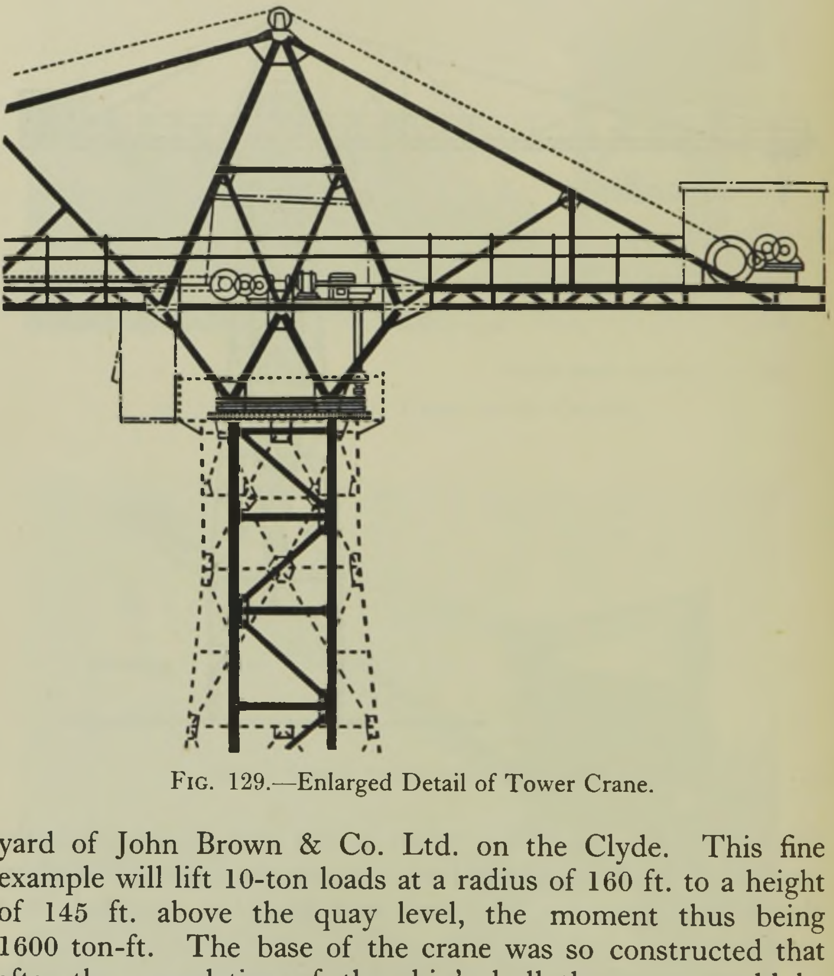


FIG. 129.—Enlarged Detail of Tower Crane.

In the background of this interesting view are seen several electric *derricks* of a special type suitable for shipbuilding.

The capacity of each is 5 tons at 55 ft. radius (275 ton-ft.) and 111 ft. height of lift. These derricks are equipped with hoisting, racking and slewing motions operated by electric motors.

Thus in shipyards various types of cranes are available for use either in conjunction or as alternatives. One can use either overhead travellers or cantilever cranes on high fixed gantries or monorails, besides derricks and tower cranes ; though the last-named seem to be the survival of the fittest.

Fitting-out Cranes.—For fitting-out service, as distinguished from shipbuilding proper, considerably heavier tower cranes have been made to handle loads of 30 tons at 100 ft. radius (3000 ton-ft. moment) and 15 tons at 140 ft. radius, lifting up to 150 ft. above the ground.

An alternative type of crane used for fitting out vessels is pictured on Plate 30, a warship being seen alongside. This useful crane will lift a load of 30 tons at a radius of 55 ft. or a 25-ton load at 73 ft. radius (1825 ton-ft. moment) or a 5-ton load at 106 ft. radius, the height of lift being 110 ft. at the 73 ft. radius. The test load for stability was 45 tons.

The position or rake of the cranked derricking jib is here controlled by a pair of heavy screws. The entire superstructure revolves on a roller path mounted on a portal gantry or tall truck, the track rails being spaced at 40-ft. centres.

CHAPTER XVII

THE CARGO-HANDLING EQUIPMENT OF SHIPS AND TRANSIT SHEDS

A GREAT deal of hoisting machinery is employed solely in transporting materials and goods between ship and shore at the numerous ports throughout the world. Some of this machinery is a permanent part of the ship's own regular equipment, while the quay cranes used constitute a valuable part of the port equipment.

At the large home ports quay cranes are more important than ship's derricks and winches, whereas at some foreign ports one has to rely mainly on the ship's own equipment when loading and discharging cargo. A maximum of expedition in this work, however, is only attained by the joint utilization or conjunction of the full resources of both the ship's own lifting gear and the port's hoisting and conveying machinery, often supplemented by a fleet of barges.

Before going on to describe such appliances in detail it will be helpful to consider briefly the various kinds of cargoes that have to be handled in the routine work of a great port.

Cargo or Freight.—In general terms cargo comprises raw materials and merchandise. All these have their own characteristics from the conveying and lifting point of view. Those materials which can be handled in mass include coal, coke, grain, oil, ore, sand, etc., and are known as *bulk* cargo. Here grabs are often applicable.

Commodities which have to be handled in units or individual large parts, or grouped in parcels, or packed in containers, are styled *general* cargo, and have to be slung from a crane hook as a rule. These comprise a mixed lot of all sorts of goods including bags of sugar, flour and cement ; bales of cotton and wool ; barrels of apples ; cases of canned goods ; crates of fruit, poultry and rabbits ; casks of tallow ;

hogsheads of tobacco; ingots of copper; logs and planks of timber; and parts of machinery.

The diversity of cargo is indeed remarkable, not only in character but also in size and weight. At one end of the scale we may have a package of provisions as little as 10 × 7 × 5 in., and at the other end a case of bacon measuring 4 ft. by 2 ft. 9 in. by 2 ft. 6 in. Some small packages weigh only a few pounds, whereas a sack of flour weighs 2½ cwt., a bale of wool 3 cwt., a bale of cotton 5 or 6 cwt., and so on up to a hogshead of tobacco weighing half a ton.

Timber cargoes again are extremely diverse. Logs or balks are usually 12 in. square, but some reach 24 in. square, their lengths ranging from a few feet up to perhaps 60 ft. Planks measure 11 × 3 in. in cross section, while deals are 9 × 3 in. and average about 16 ft. in length.

In the Port of London the *average* weight per lift of the quay cranes handling general cargo hardly reaches a ton. Actual loads rarely exceed 25 cwt., the average number of lifts per hour of a crane being about twenty.

Most cases and crates are liable to damage by rough handling. This fragility restricts the size of a parcel of goods that can be lifted out of a ship's hold without serious risk of breakage. Cargo handling would be simplified if packing cases could be made in a few standard sizes instead of in *any* size.

Long and flat packages are more liable to suffer damage in transit than those of nearly cubic shape, and should therefore be well stiffened by battens. As shipping charges are based on *capacity* and not on weight, compactness in packing saves both space and money.

The use of *containers* for the assemblage in compact form of small mixed packages (as in rail transport) might perhaps be extended to ship transport with advantage.

Perishable cargo comprises all those classes of goods which suffer rapid deterioration unless protected from decay. Such cargoes include dairy produce and fruit, also refrigerated beef, mutton and rabbits. Hence speedy transfer from ship to quay is essential.

Derricks and Winches.—The fact that cargo boats have often to visit ports which are poorly equipped with quay cranes makes it necessary to equip a ship's own decks with sufficient cargo-handling appliances to make the vessel self-sufficing. In other ports the ship's own gear can be profitably used as an auxiliary to the quay cranes available, in order to save expense and to secure greater dispatch in loading and unloading the ship.

A vessel's cargo-handling equipment comprises masts, derrick booms, pulley blocks, hoisting lines or whips and winches. There are often several jib cranes as well. This lifting gear is arranged in groups to serve each well or opening in the decks. These hatchways extend from the top deck to the hold and allow cargo to be lowered into or hoisted out of the holds. Their usual number varies from 4 to 8, according to the size of the ship. From a cargo-handling point of view the larger the hatchways the better, their actual size ranging from 12 ft. square to about 30 × 40 ft.

Sometimes substantial vertical derrick *posts* about 30 ft. high are provided, quite separate from the ship's masts. These posts are grouped two abreast at hatchways and need to be well stayed. As a rule, however, derrick booms are carried by the ship's masts, the number of booms ranging from two per mast up to six in large vessels. Outriggers are attached to the lower mast-head.

The steam and electric winches used for cargo-handling usually have not only a central barrel or drum but also a warping end on each side, clear of the main frame. Electric cables are cleaner and more convenient than steam pipes.

The combined operations of lifting and slewing need two winches, the load being lifted on one hoisting rope and slung overside by another line. As a rule it is not feasible to work more than one line on each side of the hatch, one for shore delivery and one for overside delivery to a barge.

The proportion of derrick booms and winches to masts and hatchways varies from a single boom and winch per hatch to as many as six sets of hoisting gear per hatchway. Commonly a two-masted vessel would have four hatchways, eight booms and eight winches.

Deck Cranes are a useful addition to the ship's derricks, but are more often fitted on coasting vessels than on tramp steamers. They have the drawback of being more expensive than derricks and they take up valuable deck space. A common size of crane has a moment of 40 ton-ft. and will lift a load of 2 tons at a radius of 20 ft. The usual position of such a crane is near the hatchway corners.

A drawing showing the deck equipment of the 'Mapia,' a typical cargo steamer 480 ft. long, is given on page 28 of Cunningham's "Cargo Handling at Ports," to which book reference may be profitably made for further details on this subject. In the 'Mapia' there are ten steam jib cranes, each lifting 2 tons at 20 ft. radius to a height of 14 ft. above the deck. These cranes are symmetrically placed for serving six hatchways. The twin-cylinder engines are 6 in. diameter by 8½ in. stroke and are fitted with reversing gear.

The forward mast of the ship supports four 6-ton derricks and one 30-cwt. derrick, while the rear mast supports five more 6-ton derricks. There are also nine steam winches serving the 6-ton derricks. Thus the cargo-handling equipment of such a cargo boat is planned on quite an extensive scale.

A recent large Australian liner, the 'Dominion Monarch,' is equipped with many cargo derrick-posts and with twenty-four electric winches, each capable of lifting 5 tons at a speed of 180 ft. per min., in addition to one 40-ton derrick.

Elevator-conveyor.—An alternative method of discharging cargo is by means of a portable elevator-conveyor of the twin-chain and canvas-loop type, which was first successfully used for unloading bunches of bananas, while portable *arm* elevators have been utilized for efficiently handling frozen mutton. This is a very rapid and continuous method of discharging goods of uniform size and weight, but it is obviously unsuitable for mixed cargo.

The elevator leg takes up considerable room in the hatchway, and this is not always available. Also a certain amount of working space is needed in the hold for serving the elevator foot with a continuous stream of similar packages. But the main drawback is in respect of the diversity of cargo and the difficulty of ensuring a proper sequence of discharge of mixed parcels of goods.

Cost of Handling Cargo.—When the goods are of one kind and are simply consigned to one or two individuals, they can be cheaply loaded direct into barges or into railway wagons or into motor vehicles. But when they differ greatly in kind and are consigned to various people, the goods have to be sorted and temporarily deposited in different parts of the transit shed. This may mean employing a gang of men with hand trucks, each man being allocated to a particular

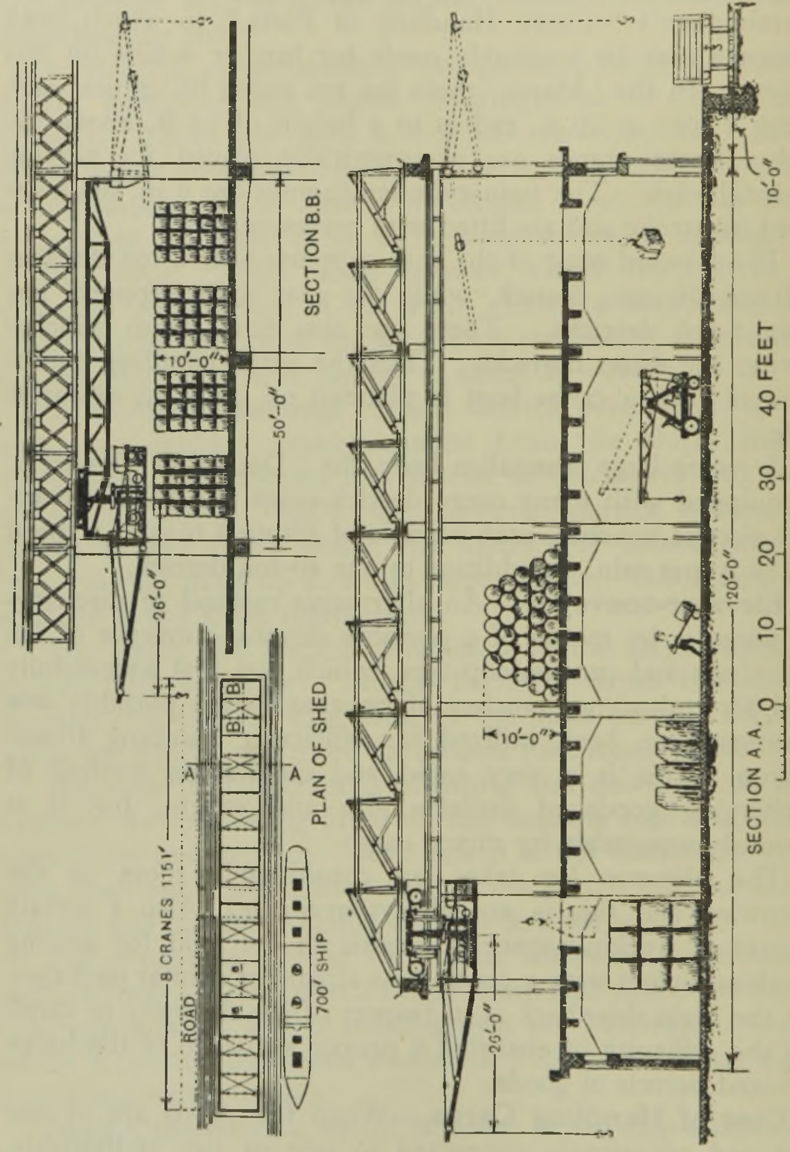


FIG. 130.—Section through a Transit Shed.

mark. Alternatively, one may perhaps use either electric accumulator trucks or gravity roller runways or continuous conveyors of several types.

In the Port of London the total charge for handling general cargo averages about 6s. per ton. This covers the whole series of operations between the ship and the transit shed, including sorting into lots. The actual charge ranges roughly from 4s. to 8s. per ton of cargo.

The use of a modern quay crane alone may cost from 4d. to 9d. for every ton of general cargo handled by it; including all working costs, capital and depreciation charges, and the wages of the crane driver.

Transit Shed Equipment.—A good idea of a modern transit shed and its equipment may be gathered from a study of a drawing (Fig. 130) taken from a very useful paper [1] by Asa Binns on port equipment. This illustration shows a railway track on the side of the shed remote from the dock, but there are actually three railway tracks on the offside and two tracks on the quayside of the shed. In the small-scale plan view is indicated the position of a ship 700 ft. long alongside the quay. This transit shed is 120 ft. wide by 1151 ft. long, and is served by eight quay cranes.

The lower view is a cross section of the shed through AA, while the upper view is a part longitudinal section through one 50-ft. bay. The latter view shows hogsheads of tobacco stacked to a height of 10 ft. above the first floor, which is served by a 1-ton electric jib crane of the *underslung* type. Such a crane is convenient and rapid, but its first cost is high and it reduces the space for vertical piling. In the lower view also is indicated a light runabout or *mobile* jib crane, a handy type which has proved of great service and achieved some prominence of recent years. (See Chapter XXV.).

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[1] See *Proc. Inst. of Mech. Engineers*, May 1932.

CHAPTER XVIII

QUAY OR WHARF CRANES

For rapidly handling miscellaneous cargo a special type of long jib crane has been developed and supplied in great numbers to the chief shipping ports. Quay cranes for general cargo are always of relatively small capacity or lifting power, seldom exceeding 3 tons, whereas the medium speed fitting-out crane for dry-dock service usually ranges from 5 to 30 tons in capacity.

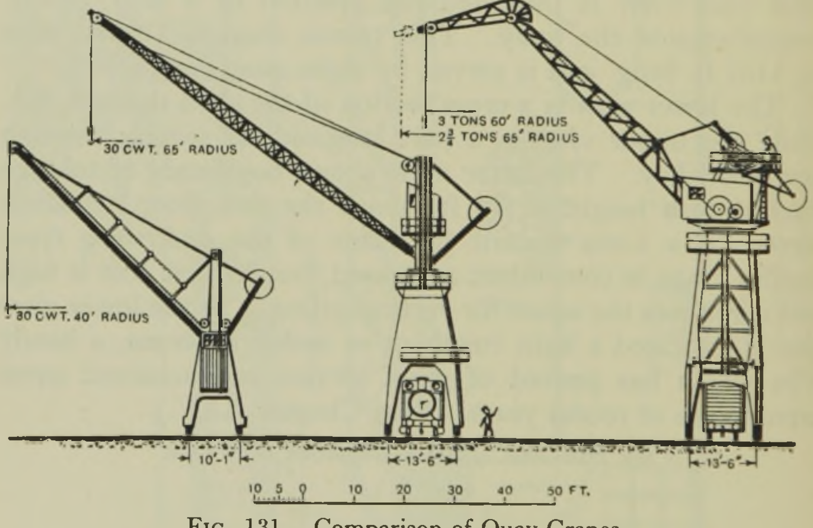


FIG. 131.—Comparison of Quay Cranes.

For many years the 30-cwt. hydraulic pedestal crane, with a radius of 40 ft. and weighing 25 tons in working order, was the prevailing type and size of quay crane, and many such cranes are still in use. By 1927 the usual hydraulic crane was still of 30-cwt. capacity, but the radius of the jib had grown to 65 ft. and the weight of the whole crane on a track of $13\frac{1}{2}$ ft. had increased to $41\frac{1}{2}$ tons.

Meanwhile the electrically operated level-luffing crane made great progress and by 1922 had developed into a 3-ton crane, weighing fully 59 tons and having a radius of 60 ft.

This interesting comparison of typical quay cranes is illustrated in Fig. 131, taken from Asa Binns' paper of 1932, entitled " Recent Developments in the Mechanical Equipment of the Port of London Authority," where two hydraulic cranes and one electric portal crane are drawn to the same scale. The great height and outreach of modern cranes is noteworthy.

The relatively meagre use of steam cranes and the rapid growth of electric cranes during a quarter of a century is emphasized in the following table, giving the numbers of cranes of different classes employed by the Port of London Authority :—

Cranes	Number in 1906	Number in 1931
Hydraulic . . .	626	731
Electric . . .	26	354
Steam . . .	34	55
Hand . . .	260	192

Despite the rapid development of electric cranes, it is noteworthy that fully twice as many hydraulics as electrics were in use in 1931. Thus hydraulic wharf cranes are still far from being extinct in the Port of London.

Asa Binns also gives the following useful classified list of cranes in actual use by the Authority :—

Cranes	Hydraulic	Electric	Steam	Hand	TOTAL
Quay . .	419	160	1	24	604
Warehouse .	312	144	...	159	615
Runabout .	...	50	...	...	50
General .	...	...	49	9	58
Floating .	...	...	5	...	5
TOTAL .	731	354	55	192	1332

The actual *spacing* or distribution of quay cranes varies somewhat according to trade requirements, but taking four modern docks used by general-cargo vessels, the length of quay space allotted to each crane ranges from 45 to 67 yards and averages 53 yards.

Although in the most recent 30-cwt. *hydraulic* cranes it has not been thought worth while to introduce the principle of level-luffing, yet the vast majority of *electric* cranes erected during the last thirty years have been fitted with level-luffing gear, which not only saves much power but also greatly facilitates the rapid operation of quay cranes.

Hydraulic cranes are very safe and reliable, also as nearly foolproof as possible, and they are relatively low in first cost. But they are more wasteful of power than electric cranes when working on variable loads, and it is certainly easier and cleaner and more efficient to transmit power by electric current at 480 volts than by water at a pressure of 800 lb. per sq. in.

Yet *reliability* is the most important requirement in a quay crane, while speed is the second and economy of operation is only the third. Very few quay cranes work more than 20 hours a week, a fact which makes low power consumption relatively unimportant. In 1932 the average working cost of pressure water was about 1s. 4d. per 1000 gallons, excluding capital charges and the cost of distribution.

Owing to the fact that a modern electric 3-ton quay crane costs something like £4000, and yet seldom works for more than 1000 hours in a whole year, the capital and depreciation charges of such a crane amount to about as much as the total cost of power, repairs and maintenance.

Hydraulic Cranes.—It was in the year 1864 that hydraulic power was first applied to quay cranes, and the hydraulic crane still shows to best advantage when handling heavy uniform loads, *not* light variable loads. Electric cranes appeared between 1890 and 1900, and they soon became powerful rivals to hydraulic cranes.

Writing early in this century Joseph Horner remarks that water is used chiefly for *fixed* cranes, for which it is an admirable source of power, though systems of jointed or walking pipes provide means for its conveyance through a range of a few feet of special types of portable cranes. Many of the great fixed cranes on our quays and dock-walls are of the hydraulic type, and so are many of a much lighter class in warehouses.

The movement of a hydraulic crane is smoother and quieter than that of a steam crane and is more perfectly under control. The load is a question of water-pressure and of the area of ram or piston. The travel of the hook or height of lift is a matter of the stroke of the ram, as altered by the action of a series of multiplying pulleys. The cylinders and chains occupy a good deal of room.

Though perhaps more complicated and massive, load for load, than a steam crane, a hydraulic crane is preferable to the latter for *fixed* wharf duty and for warehouses. Also it is a fair rival to steam for heavy work on docksides. An objection to water power is *frost*, but this is guarded against in cold climates by bringing the pipes underground and by mixing glycerine with the power water. The precaution can also be taken of letting the water out of the pipes and cylinders at night.

Regarding hydraulic cranes in general, Horner remarks that fixed hydraulic jib cranes are used for both indoor and outdoor service, the jibs being either horizontal in some cases, to take a trolley, or inclined in other cases. Separate cylinders actuate the lifting and the slewing movements, the dispositions of the cylinders being settled by convenience, since the direction of motion of the chains can be readily altered by guide pulleys.

The frames of hydraulic cranes more or less resemble those of the steam-crane types, such as wall cranes, wharf cranes and ingot cranes. An application where hydraulic power has found great favour is in the riveting cranes which travel on rails and have walking water pipes.

In some hydraulic cranes rotation or slewing is effected by a water cylinder, placed horizontally below ground-level, having a *rack* attached to a continuation of its piston which engages with a wheel keyed on the bottom pivot of the crane. In some types of crane the chains pass around pulleys from the piston head and pull round a chain-wheel at the bottom of the crane. In other types the lifting cylinders are fixed and the *ram* moves, the hoisting chain returning over pulleys from below upwards.

Fig. 5 (page 8) illustrates one type of light hydraulic crane in which the lift is direct, by the communication of the movement of the ram A to the jib B.

The usual operations of a hydraulic crane are lifting, slewing or turning and radial motion or luffing. Valves operated by hand levers control the admission and exit of the water from the various cylinders. There is a minimum of transmissive mechanism. A motion must have at least one actuating cylinder, while some motions need two cylinders, one for movement in each direction. But in *lifting* one cylinder suffices, because the load itself returns the ram on release of the pressure water.

It is mainly in the cylinders that designs vary in cranes of like functions. The position of cylinders is very flexible, because the motion of a ram can be transmitted in any direction by means of guide pulleys and chains. Hence hydraulic cylinders are found disposed horizontally, vertically and inclined, some being placed so as to afford counterbalance to the forward tipping moment of the crane.

As the range of operations is generally larger than the stroke of the ram, two or three sets of multiplying pulleys are arranged side by side, thus increasing the speed of lift at the expense of the loss of lifting power. Neglecting friction the relation is

$$\begin{aligned}\text{Load on hook} \times \text{speed of hook} &= \text{load on ram} \times \text{speed of ram}\\ \text{or load lifted} \times \text{height of lift} &\\ &= \text{fluid pressure} \times \text{area of ram} \times \text{stroke.}\end{aligned}$$

But there is a considerable loss of energy due to the friction of the cup leathers gripping the rams and to the friction of the chain sheaves on their pins, allowing for which the true relation becomes

$$\frac{\text{Hook load}}{\text{Ram load}} = \frac{\text{ram speed}}{\text{hook speed}} \times \text{mechanical efficiency.}$$

The application most favourable to the economics of hydraulic cranes is cargo-handling on wharves, where rows of cranes can be supplied from a common service of pressure-water, either public or private.

A former usual type of hydraulic wharf crane had a fixed jib and a limited range of ground travel by hand-power, walking pipes being fitted to permit this movement. Two lifting powers, of 10 and of 30 cwt., were provided, the height of lift being 40 ft. with a jib reach of 25 ft.

At Liverpool hydraulic cranes of an unusual type travelled on the roofs of certain transit sheds, rails being laid on the ridges and eaves of these buildings. The lifting and luffing were effected by cylinders lying within a sloping casing going down the roof, and the slewing cylinders were located in a box girder forming the base of the carriage. The capacity of these cranes was 30 cwt. lifted through a height of 76 ft. at a speed of 150 ft. per minute.

QUAY CRANE SUBSTRUCTURES

Because of the high sides of large ships it is necessary to mount cranes in such a way that the jib foot is placed high enough for the jib to clear completely the hulls of ships lying alongside the quay. When ships are in dock the question of variation in level due to the rise and fall of the tide does not occur, but it is a serious matter in tidal estuaries and harbours, where the water-level may vary as much as from 20 to 40 ft. at different times.

Hence crane pedestals tend to get so tall as to become fairly high travelling towers. Alternatively quay cranes may be mounted on the flat roofs of lofty transit sheds, perhaps three stories high; as at the Gladstone Docks, Liverpool, where forty-six cranes travel on tracks laid on the shed roofs. In addition to these light roof cranes, however, there are twelve lofty quayside portal cranes.

Crane pedestals or substructures are broadly divided into three types, namely, non-portal, portal and semi-portal. The old non-portal or unpierced pedestal was of plated construction, of low height and of small gauge, usually 4 ft. 8½ in., but it is now almost obsolete.

The *portal* or arched pedestal crane is the prevailing type, having two legs spanning at least one railway track, which means a minimum crane track of 10 ft. 1 in. gauge and commonly of 13 ft. 6 in. Wagons can pass through the portal or opening, which is made high enough to give adequate head-room for the passage of locomotives. Other common rail gauges for dockside portal cranes are 15 ft. as at Liverpool and 18 ft. as at Southampton. Occasionally the rail gauge on certain wharves goes up to 26 ft., thus enabling the cranes to clear three railway wagons abreast.

In the *semi-portal* type of pedestal the back leg is either shortened or even omitted altogether, the back rail being carried at a much higher level than the front rail, on a girder supported from the transit-shed structure, which must be suitably strengthened. This ingenious design economizes room on the quay and causes but little obstruction. When the quay margin is too narrow to accommodate even one leg of the pedestal, the entire crane has to be carried on the roof of the shed.

An unusual or unique combination design is found at the port of Hamburg, where, mounted on a common semi-portal pedestal or travelling tower, there is a 3-ton radial jib crane at a high level and also, rather lower down, a light straight line transporter, with a horizontal jib some 40 ft. high, on which runs a trolley with a travel of 65 ft., working quite independently of its companion above. Several of these *combination cranes* have been installed.

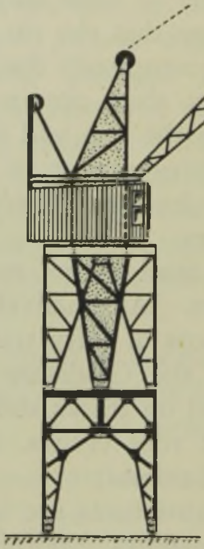


FIG. 132.—Tall Quay Crane.

The structural design of a quay crane pedestal or gantry is outlined in Fig. 132. It encloses a lattice steel mast, which rotates on a footstep bearing supported by a stiff cross girder built into the steel gantry over the portal. The lattice mast or centre-post is carried upwards well above the driver's cabin and is steadied by at least four steel rollers running round

PLATE 31

Babcock & Wilcox Ltd.

3-TON PORTAL CRANE.

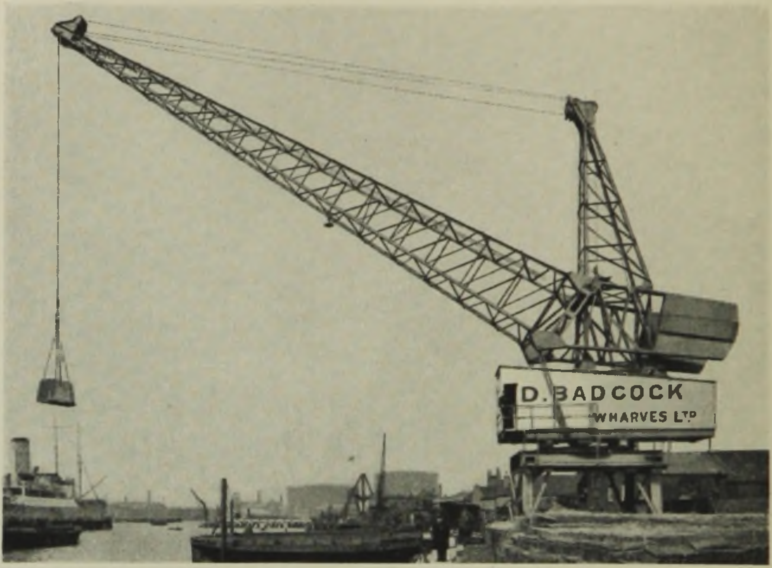
Babcock & Wilcox Ltd.

SEMI-PORTAL QUAY CRANE.

Babcock & Wilcox Ltd.

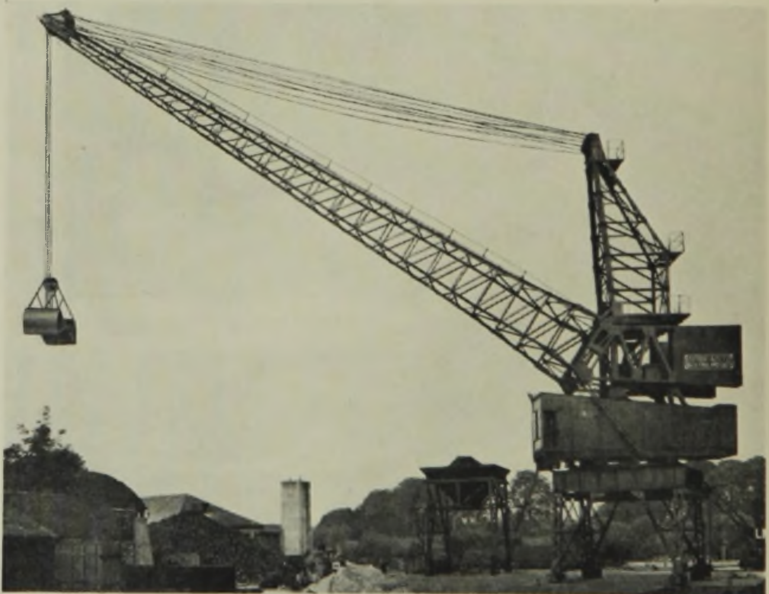
7½-TON SHIPBUILDING CRANE.

[*To face page* 224.



Stothert & Pitt Ltd.

Crank-operated Level-luffing Crane.



Stothert & Pitt Ltd.

Level-luffing Crane equipped with Grab.

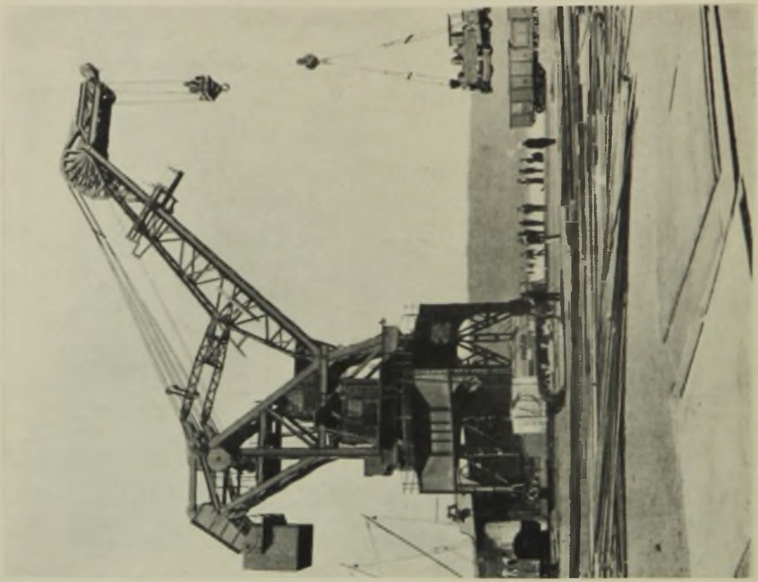
Stothert & Pitt Ltd.

QUAY CRANE LOADING CARGO.

Stothert & Pitt Ltd.

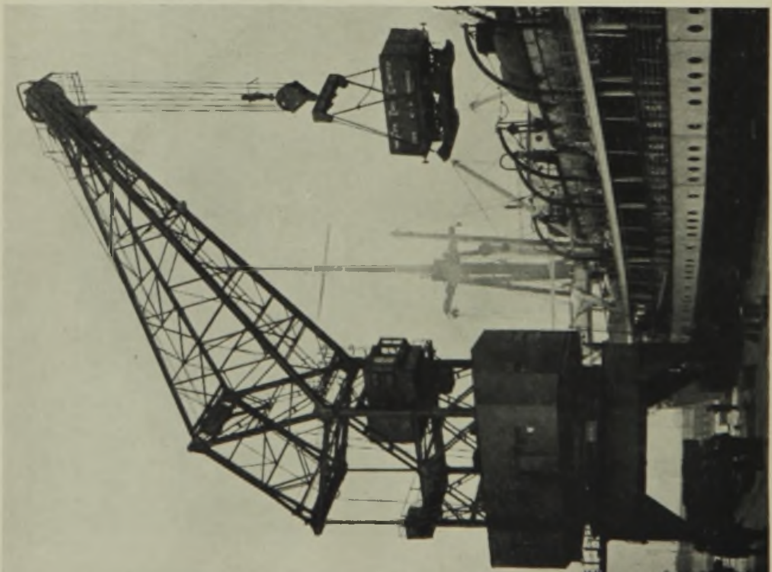
ELECTRIC LOCOMOTIVE CRANE WITH SKIP.

PLATE 34



Babcock & Wilcox Ltd.

80-ton Wharf Crane of 62½-ft. Radius.



Babcock & Wilcox Ltd.

35-ton Coaling Crane of 60-ft. Radius.

To face page 225.]

with it on a fixed circular path. At the summit of the mast are mounted the necessary sheaves for guiding the luffing ropes.

A less lofty pedestal of the portal type running on eight wheels is outlined in Fig. 133, which also indicates how two of the travelling wheels on each leg are driven from a centrally situated motor through bevel gears and shafts. These wheels sometimes have a central flange running between two flat-bottomed rails, but more commonly are double-flanged turned cast-steel wheels. Travelling speeds along the quay range from 50 to 100 ft. per minute.

A crane pedestal must be designed to withstand not only the dead load of the machine and the live forces acting on the revolving superstructure, but also the gales of wind and the inertia forces due to starting and stopping the loaded jib when slewing.

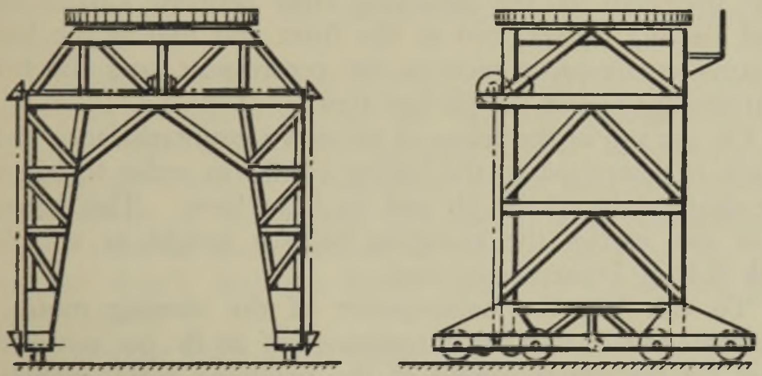


FIG. 133.—Portal Type of Crane Pedestal.

The travelling motor of 8 or 10 H.P. is equipped with an electro-magnetic brake, which prevents the crane from being accidentally blown along the rails in a heavy gale. To give additional stability rail clips and blocking screws are fitted, as a useful safeguard.

One method of collecting the necessary electric current for operating the motors is to run bare copper leads, supported on insulators, in a trough close to the track rail, leaving uncovered an opening in this trough to clear a collector arm on the crane truck.

Another method of collecting current, suitable only for short runs, is by means of a trailing cable connected to a junction box fitted to the crane truck, or by means of an automatic spring-operated cable drum.

Slewing Gear.—The slewing or turning gear of an electric quay crane of the type shown in Fig. 131 is operated by a separate motor of about 8 B.H.P. driving through spur and bevel gears on to a pin-type slewing rack, which is fixed to the top of the pedestal structure. A foot brake is fitted to check the angular momentum of the revolving superstructure, and a slipping device is also desirable.

The roller path is formed from steel joists bent to a circle, protected on the top by a thick renewable wearing plate. The rack teeth consist of stiff pins securely fitted into the joists. The underside of the revolving steel bedplate carries four steel slewing rollers, two at the front and two at the back. A stout centre-piece receives the centre-post, and the front is arranged to carry the jib-foot pins.

On the top of the frame is pivoted a counterbalance lever, which is connected to the luffing cranks in order to balance the deadweight of the jib and its head lever. This balance lever also carries the swinging balance weight or a ballast tank holding broken scrap iron.

To calculate the horse-power of the slewing motor, a common rule is to allow a resistance of 30 lb. per ton at the hook for the entire weight of the revolving mass, including the jib and its load. For example, in a 5-ton by 40-ft. radius crane having a total revolving weight of 33 tons, the power required at a slewing speed of 300 ft. per min. would be

$$33 \text{ tons} \times 30 \text{ lb. per ton} \times 300 \text{ ft. per min.} \div 33000,$$

which works out to 9 H.P.

The slewing speeds of quay cranes range from about one turn to one and a half per minute, or from 250 to 400 ft. per min. at the hook.

Hoisting Gear.—In the smaller sizes of quay cranes the range of lift of the hook is from about 45 ft. below the wharf level to about 60 ft. above it. The load is hoisted at the rate of about 200 ft. per min., ranging upward to a maximum of 300 ft. per min. To some extent the best hoisting speed is governed by the depth of the hold of the vessel being unloaded. The speed should be greater for a big liner than for a shallow coasting vessel, where the height of lift is much less. Another factor is the rate of goods handling at the feeding point and ashore, it being useless to provide speeds in excess of the abilities of the stevedoring gangs.

In modern cranes a separate reversing motor of 40 to 50 H.P. is provided for hoisting, the old method of working all the motions by one motor being obsolete. The multiple-motor system is both more speedy and more reliable, needless gearing and clutches being eliminated. Transmission is through machine-cut spur gearing, the motor extension shaft being fitted with a steel pinion and an automatic electro-magnetic brake, capable of holding the full load on the hook. The intermediate shaft carries a spur-wheel and a hoisting pinion meshing with the main wheel keyed on a cast-iron hoisting barrel.

The barrel or drum is grooved to take the rope and is made long enough to prevent the rope overlapping. It runs loose on a fixed shaft and is suitably bushed with gunmetal. This *free-barrel* arrangement permits a light load to be lowered independently of the motor, the barrel being disconnected and its rotation controlled by a brake. Between the disengaging clutch and the motor controller an interlocking device is fitted.

For heavier loads a free-barrel device is hardly applicable, because of the extra exertions of the crane driver in operating the brake. A better practice is to arrange the hoisting motor for *potentiometer control*, involving a special controller giving plain series control when hoisting only ; whereas when lowering the series field coils of the motor are connected in parallel with the armature, thus giving the series motor the characteristics of a shunt-wound motor and causing the motor to act as a generator of current. This braking action prevents all possibility of the falling load taking charge and driving round the motor armature at an excessive speed.

The hoisting rope is made of special steel wire of 90 to 100 tons per sq. in. tensile strength, with a factor of safety of six. It is furnished with an overhauling weight, a short length of chain and a swivelling hook carried on a ball bearing.

An overwinding gear is provided to cut off the current in the event of the crane driver overwinding the hook. This consists of a quick-break trip switch of the self-resetting type, positively operated and capable of adjustment.

The levers and controllers for operating a quay crane are conveniently arranged in a driver's cabin of sufficient size, constructed of timber covered with roofing felt and fitted with the necessary windows and door. Suitable ladders and platforms give access to the portal pedestal, the cabin and the jib.

CHAPTER XIX

LEVEL-LUFFING MECHANISMS

No attempt will be made here to deal with all the designs of level-luffing gears that have appeared during this century, but there are two types of outstanding merit and importance which will be considered in some detail. These may be briefly styled the 'Wylie Lever Gear' and the 'Toplis Crank Gear,' from the names of their respective inventors. Both types are used extensively and both work beautifully.

Each of these successful gears utilizes a perfectly balanced jib or boom, positively linked to the luffing mechanism of the crane and giving a horizontal path to the hook throughout a long range of radial movement. Either of them is distinctly better and safer (though rather dearer) than those types which employ a multiplicity of long running ropes to control the derricking motion of the jib and maintain a horizontal path of the load being lifted. The Wylie gear came out fully ten years earlier than its rival, and has enjoyed a long period of success.

The Wylie Lever Gear.—This invention was covered by a patent specification of much technical interest (namely, No. 3658 of 1909), taken out by a Scottish engineer, Hamilton Neil Wylie, then of Edinburgh, who later became associated with the firm of Babcock & Wilcox Ltd., of London and Renfrew. His lengthy specification is entitled " Improvements in the Luffing Gear of Cranes," and it indicates several alternative designs in a rudimentary form.

The principle of Wylie's invention is outlined in Fig. 134, this diagram being taken from a paper by Sir James Kemnal on " Boiler and Crane Construction," read in 1923 before the Institution of Mechanical Engineers at Glasgow.

Wylie's invention relates to improvements in cranes having jibs that transport the load by a rotary movement or angular displacement of the jib in a vertical plane, the object being to supply means of transporting a load radially with as little expenditure of power as possible.

In the older types of cranes the operation of derricking entailed the lowering and lifting of the load on the hook as well as the centre of gravity of the crane jib. Although means of traversing the load without this drawback had already been used, such means had increased the complexity of the crane and the wear on the moving parts.

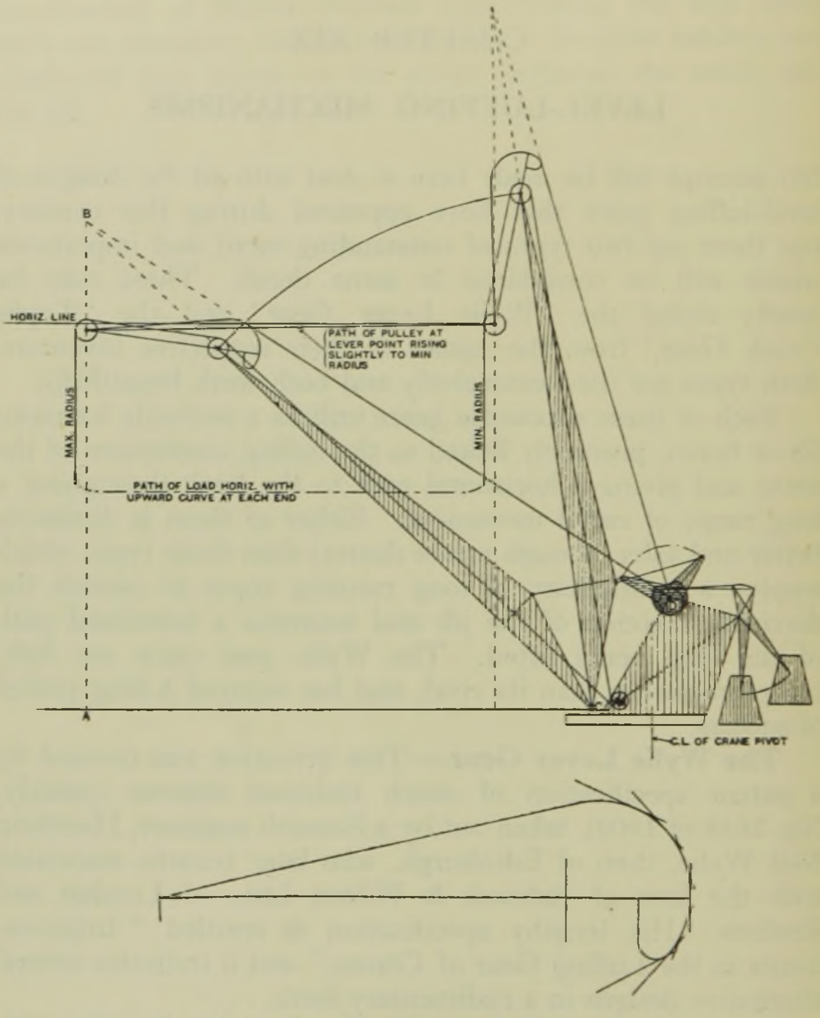


FIG. 134.—Kemnal's Diagram of Wylie's Gear.

The object of this invention is to arrange a crane so that its load is traversed horizontally, while the centre of gravity of the crane is kept at one level, and also so that the combination of details is simpler and the wear on moving parts is less than in existing types of cranes for similar duty.

In Wylie's crane the jib consists of a rigid strut with a folding lever of special shape pivoted on its outer end. The inner end of the jib is pivoted to the main structure and the jib is supported by a tension line or link to the structure. The load is suspended from the free end of the jib, and is traversed or luffed by the jib rotating outwards and downwards. A counterweight is employed which takes the form of a loaded lever linked directly to the jib and moving through an angle. The jib is clearly balanced if the centre of gravity remains at a constant level as the jib swings out.

Wylie balances the jib in two ways: firstly, in respect of its own weight by using a counterpoise, and secondly, in respect of the weight of the load on the hook by means of a *compensating gear* extending between the mast or superstructure and the jib itself. This ingenious gear permits the jib to rotate freely in a vertical plane, and, by being in communication with the hoisting line, it exerts an effort on the jib that is always equal and opposite to the effort exerted by the suspended load.

According to the weight of the load to be lifted the hoisting gear varies in complexity from a single line to a tackle of many sheaves. Wylie's proposed form of compensating gear is different for different complexities of hoisting gear, but in every case the load is transported at a constant level.

From the illustrations it will be seen that the crane is equipped with a specially shaped folding lever at the top of a braced jib, which luffs the load in a horizontal line without interfering with the fair lead of the hoisting rope. This feature counteracts any tendency of the loaded jib to luff in or out, the brake fitted to the luffing gear being only needed to bring the jib to rest promptly at the desired position.

The quadrant or folding lever on the jib head is guyed to the frame of the crane by wire ropes passing round the curved tail of this lever, whose angular position is thus controlled as the jib moves inwards or outwards. The absence of all running ropes, other than the hoisting rope itself, is clearly an important and valuable feature of this design in reducing friction and wear.

In an actual 2-ton cargo-handling crane the luffing gear is operated by a separate small reversing motor of only 5 H.P., driving steel luffing cranks through spur and bevel gears. The longer arms of the cranks are linked to the jib by rods, which actuate the jib and partly support its deadweight. The shorter arms of the cranks are connected to a balance weight in such a way that the jib is completely balanced throughout its swing. Thus the travel of the jib is limited by the throw of the cranks and is prevented from exceeding the maximum radius.

The luffing speed is rapid and is nearly uniform, though it automatically decreases as the limit of the jib's travel each way is neared, thus checking the motion gradually, while an efficient magnetic brake is fitted to permit of high-speed working. Self-setting limit-switches prevent over-luffing in either direction of motion, and a radius-indicator is provided.

Of all the types of machines that might perhaps justify the name *crane*, in bearing some resemblance to the *bird* of that name, the lever level-luffing crane is the one to be selected. Figuratively speaking it possesses legs, a body, a tail, a neck and an active beak. The resemblance of the machine to the bird becomes even closer when the machine is equipped with a grab, with which it actually seizes hold of a quantity of loose material at frequent intervals.

Returning now to Kemnal's explanatory diagram (Fig. 134), this clearly illustrates the lever gear for balancing the jib and indicates the path of the load from the greatest to the least radius of the hook. The slight rise in the curve at each end of the travel serves to check the movement automatically, and is therefore beneficial. The folding lever or ' beak ' at the end of the jib carries two sheaves for guiding the hoisting rope, and is controlled in position by wire ropes anchored to the frame of the crane as the jib is luffed.

The design of this jib lever is of some technical interest. To obtain the shape of its rounded tail draw a vertical line AB through the point of the lever and another line BC through the centre of the jib. From the intersecting point B draw a third line BD to the point at which the back guys are attached to the frame of the crane. Then BD forms a tangent from the fulcrum of the lever and gives one point in the required curve. On repeating this operation at various points between the limiting radii, we eventually arrive at the correct shape of the curved tail which the back guy-rope has to embrace.

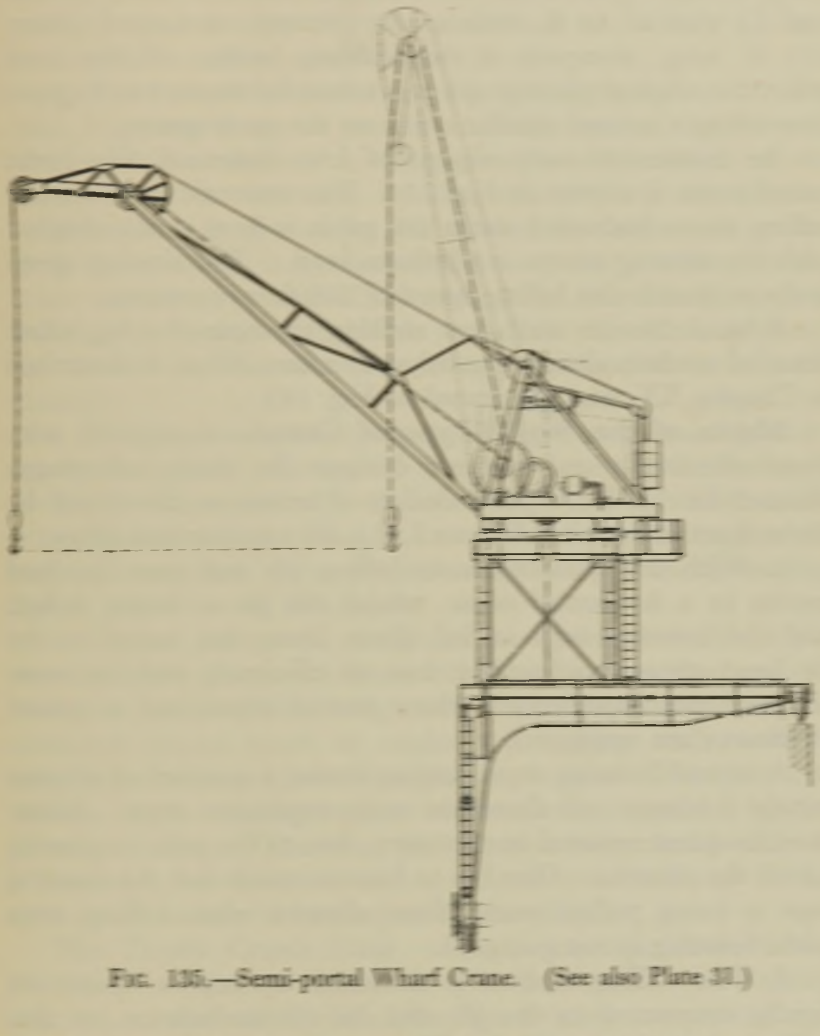


FIG. 136.—Semi-portal Wharf Crane. (See also Plate 31.)

The balancing of the jib is here accomplished by means of a swinging weight, carried on levers on the back of the revolving structure of the crane, and linked up to the jib in such a way that as the load on the hook travels outward the swinging weight travels in the opposite direction. This method has the merit of not only balancing the jib but of counteracting the marked shock on the structure evidenced when an unbalanced jib is in operation.

Plate 31 depicts an electric jib crane with a balanced lever-luffing jib, made by Babcock & Wilcox Ltd. for a shipyard at Dumbarton. This crane can handle 4 tons at 90 ft. radius and 7½ tons at 45 ft. radius. It operates on a steel gantry 470 ft. long, alongside a shipbuilding berth. At the time when the original photograph was taken the crane was engaged in erecting a second similar crane on the same gantry.

An instructive early design of lever-balanced *semi-portal* wharf crane is shown in Fig. 135. For convenience the small luffing motor indicated above the cabin is here made identical with the slewing motor at platform level. The slewing speed is about double the luffing speed of 150 ft. per minute.

A much heavier and more striking example of a big wharf crane of modern design erected at Durban, Natal, is described in Chapter XX, and illustrated in Fig. 143.

Merits of the Wylie Type of Crane.—Compared with some alternative and cheaper designs the many advantages claimed for H. N. Wylie's design of crane, as developed by the makers (Babcock & Wilcox Ltd.), are summarized below :—

1. With the balanced lever-luffing jib and gear the load moves in a *horizontal plane*, whilst the jib is being luffed, and the hoisting rope is led direct from the barrel to the jib head, thus avoiding the loss of efficiency and the wear on the ropes experienced where reeved ropes and a system of sheaves are employed.

A reeved hoisting rope passing round a number of sheaves entails a longer and therefore more expensive rope. Moreover, frequent renewal is necessary, due to the wear in passing round the sheaves. One has to bear in mind that the hoisting rope is being pulled round these sheaves when luffing, even when hoisting is not going on.

2. The luffing motion is actuated by cranks which are rigidly connected to the jib and its counterbalance, so that luffing ropes are avoided. Thus the jib is *positively driven* in and out, and is not dependent on its own weight for stability. This is an important point in a high wind, when the jib is at its minimum radius, which is a critical position for a rope-luffed jib.

3. The jib is *balanced* in all positions, either with no load

or with any load, and the swinging ballast is carried on a structural arm, so that it moves in harmony with the jib. Thus the force required to move the jib is only that necessary to put the load in motion and to overcome the friction of the moving parts. Hence the *power* of the luffing motor is quite small compared with the power needed to derrick a crane fitted with an ordinary unbalanced jib.

4. The counterbalance weight or swinging ballast on this crane is arranged not to pass down either side of the driver's cabin. This permits of a *cabin of ample size*, instead of one whose width is restricted by the necessity of the balance weights swinging close along the sides of the cabin. In cranes of the latter design it is necessary to keep the revolving frame rather narrow to permit of the passage of these weights, thus reducing the space available in the cabin for the machinery and the driver, and also preventing the effective use of side windows.

5. The jib-head sheave, when luffing, moves in an approximately level path. Hence the *free rope* between the load and the jib head is practically of the same length at minimum as at maximum radius. This is a considerable advantage when working in a wind, as the pendulum motion of a short hanging rope is only of small amplitude.

6. Due to the special design of the folding-lever jib, there is a very *ample clearance* underneath the jib at maximum radius. Moreover, a jib of this design can be operated more freely in restricted spaces (such as under the rigging and yards of shipping) than any type of straight jib of equal lift and radius, because of the smaller radius of the circle described by the jib when luffing. The lever jib is particularly useful when it is necessary for several cranes to plumb one hatchway or the same barge, either in loading or discharging.

The Toplis Crank Gear.—The patent Specification No. 213949 for " Improvements in Jib Cranes " is in striking contrast to that of Wylie's, the latter being very long and detailed, whereas the former is singularly brief and modest. It was also some fourteen years later in date than Wylie's, the actual date of the application being July 6th, 1923. Coupled with the name of Claude Martineau Toplis (a former chief engineer of Stothert & Pitt Ltd., Bath) is the name of his firm and that of W. W. Padifield as joint patentees.

In this specification there is no specific reference made to any level-luffing gear, which must therefore have been the subject of an earlier Toplis patent. The claim is merely for the combination of a crane jib having its lower end bifurcated, a machinery house between the two branches of the lower end of the jib, a luffing crank which can rotate through 360° and a link which is pivoted to the crank and to the jib.

Applications of the Toplis gear are illustrated on Plate 32. The bifurcated tail of the jib is so weighted that the jib is balanced about its pivot in all positions. A link on each side of the cabin connects the tail of the jib to a crank (of about 3-ft. throw), mounted on a shaft, which can be rotated through a complete circle by suitable gearing and an electric motor or other source of power. See also Plate 33.

In a crane so constructed the operator in the cabin has a clear view of the work to be done, unobstructed by any part of the crane. This crane has the further advantage that in the event of power being left on the crank shaft by some accident or oversight, the crank can still continue to rotate without any harm being done. The jib will merely be luffed in and out indefinitely, without the need of employing any devices (limit switches) for automatically cutting off the power, when the jib has reached either of its limiting positions.

Moreover, when the jib is thus operated by a crank, the radial movement described by the hook depending from the nose of the jib will be a simple harmonic motion, giving the greatest speed at the centre of the stroke and slowing down to zero at the end of the stroke, this being ideal for the luffing motion of a crane.

Some other merits claimed for the Toplis cranes, as made by Stothert & Pitt Ltd., are summarized below :—

1. The *simplicity* of construction promotes ease of control, reliability and maximum efficiency, while the cost of upkeep is low. The robust construction of the jib ensures that the load on the hook does not ‘ dance.’

2. The jib being in *perfect balance* it is safe even without brakes with any load and at any radius. As the resultant of the vertical load and the pull on the rope passes directly through the jib pin, the jib is always in stable equilibrium.

3. The jib being balanced it follows that even if the con-

necting links which hold the jib were removed, the jib would still remain in any position within its working range, no matter what load there might be on the hook. Thus the luffing gear has merely to overcome rope and pin friction and air resistance. Consequently the luffing motor responds readily to every movement of the controller handle and a high speed of luff can be obtained with but slight consumption of power.

4. When varying the radius the load moves at a *constant level*, thus enabling the driver to handle the load with much greater ease than in a non-compensated crane.

5. No ropes are needed for luffing or for jib balancing, the hoisting rope being the only one required. Also there are no reverse bends in the reeving of the rope.

This single rope, however, is of great length, as it does not pass direct from the hook to the hoisting drum. From the hook the rope passes in series over two jib-head sheaves, then to a sheave on top of the mast, then returns to a third jib-head sheave, then back to a second mast-head sheave and finally descends to the hoisting drum.

As the hoisting rope runs three times between the jib head and the mast head it follows that a reduction of each foot in this variable distance during luffing means a lengthening of the free rope between the hook and the jib head by exactly 3 ft., thus giving automatic compensation and preserving horizontal luffing. It is the correct relationship between the positions of these various sheaves and the jib-foot pivot that ensures the desired level-luffing effect.

The Toplis Rope-luffing Gear.—In an earlier design of Toplis crane, diagrammed in Fig. 136, there was not only a hoisting rope, as shown in full lines, but also a pair of luffing and balance ropes, as indicated in dotted lines. One end of each luffing rope is fixed at A, the rope passing over the sheave B to the luffing barrel, then after a few turns round the barrel over the sheave C and on to the jib counterbalance weight. Thus the simplification of detail that was effected in the 1923 design was substantial.

As the pull on the luffing rope is constant for all positions of the jib, it follows that a constant weight will balance the jib in any position, either with or without the load. To prove this let *ab* (in the geometrical diagram Fig. 137) indicate

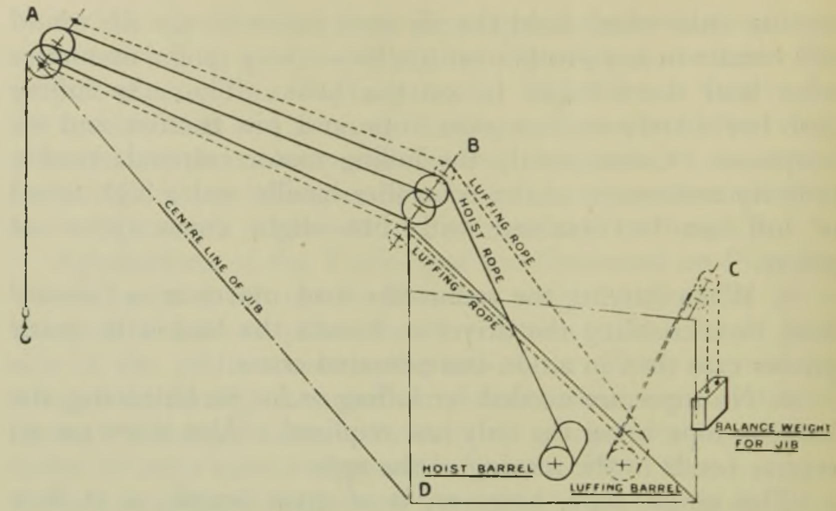


FIG. 136.—Diagram of Toplis Rope-luffing Gear.

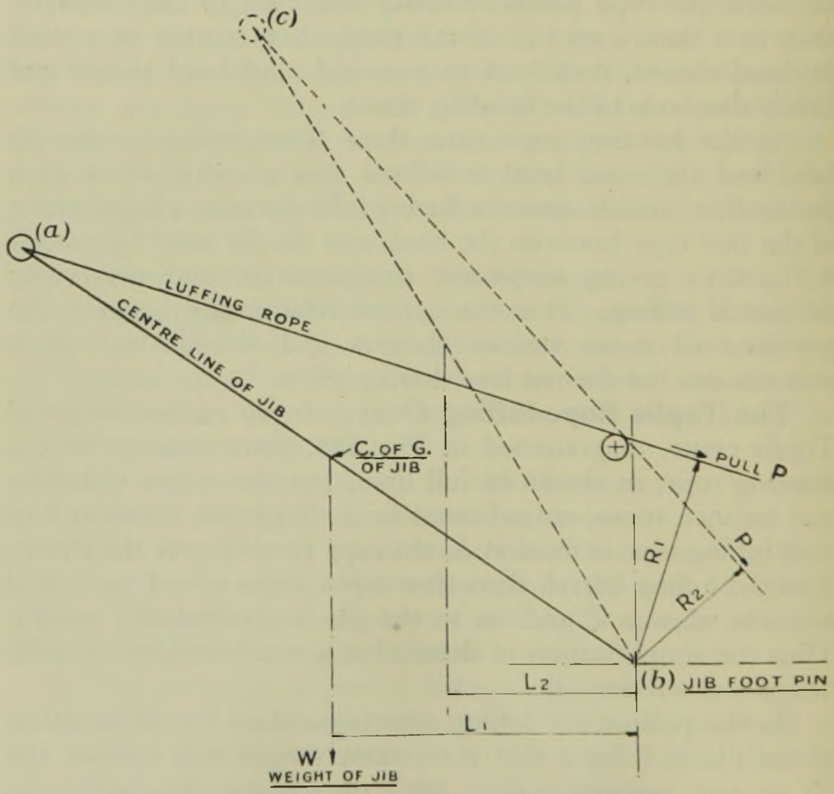


FIG. 137.—Diagram of Forces on Crane Jib.

the position of the crane jib, and let us take moments about *b* through the jib-foot pin, thus

$$P \times R_1 - W \times L_1 = 0,$$

or

$$P = W \times \frac{L_1}{R_1},$$

where W is the weight of the jib, acting at its centre of gravity, and P is the pull on the luffing ropes required to balance the jib.

Now let the jib be brought to another position *cb*, shown dotted, then we have

$$P \times R_2 = W \times L_2,$$

or

$$P = W \times \frac{L_2}{R_2}.$$

In this particular design of crane the ratio $L_1 \div R_1$ is always made equal to the ratio $L_2 \div R_2$, which means that the pull P on the luffing rope is constant for a given jib weight W. In other words a constant pull in the luffing ropes will always perfectly balance the jib at any radius whatever.

Moreover, it can be shown that the *resultant* of all the forces acting on the jib-head sheaves goes directly down the centre line of the jib and through the jib-foot pivot for any radius and for any load. Hence the jib is a strut free from any bending moment due to the load, and it can therefore be built with a minimum of weight at a relatively low cost.

Power Saving.—In the instructive diagram (Fig. 138) two

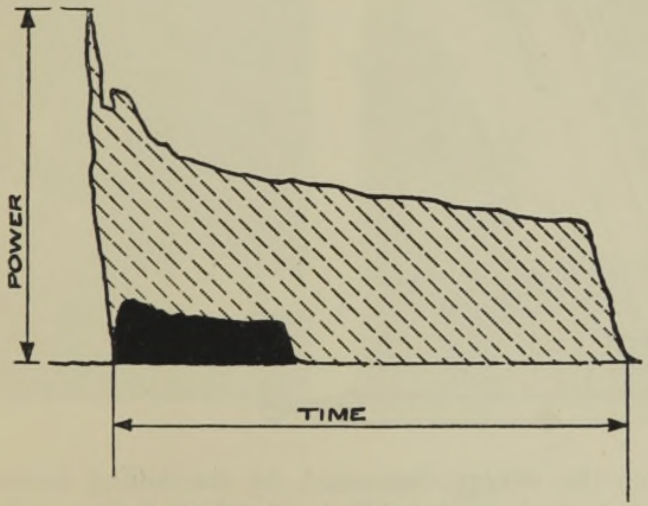


FIG. 138.—Load Graph.

load graphs taken by a recording wattmeter have been superposed for ready comparison. The large area cross-hatched

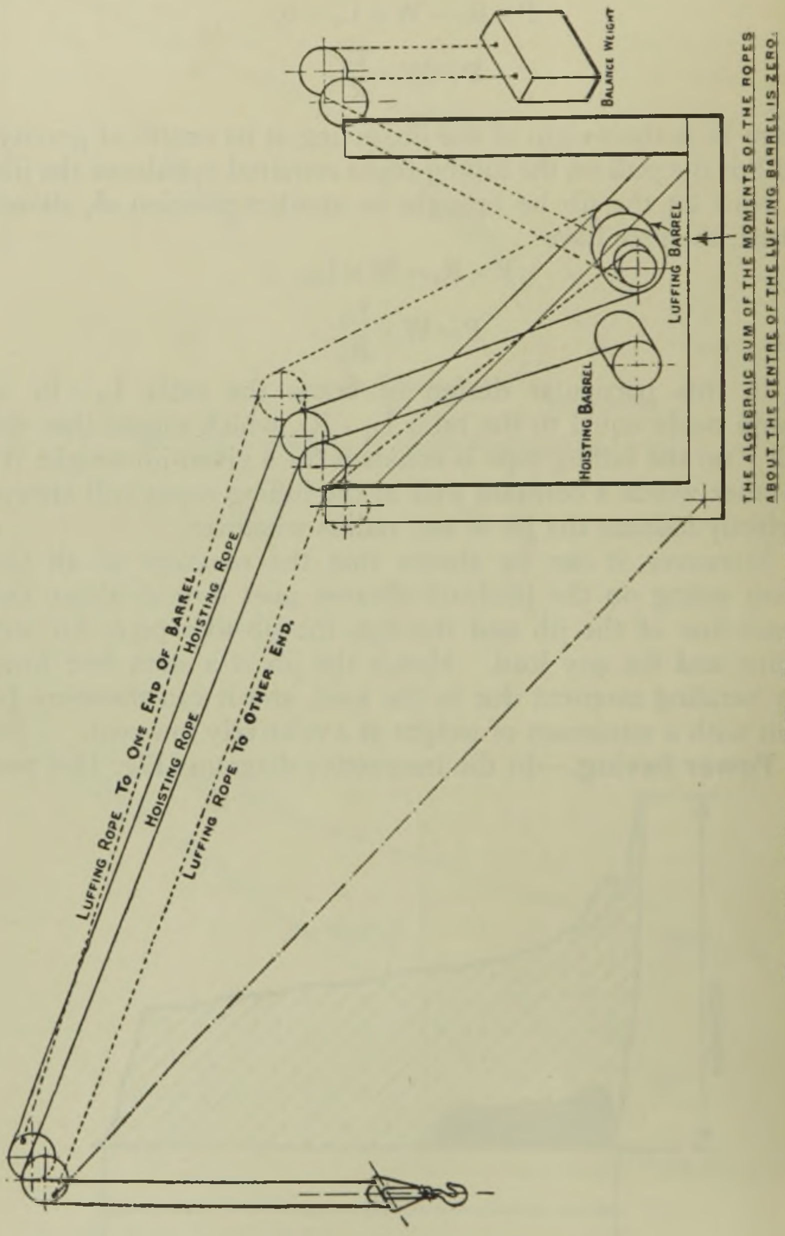
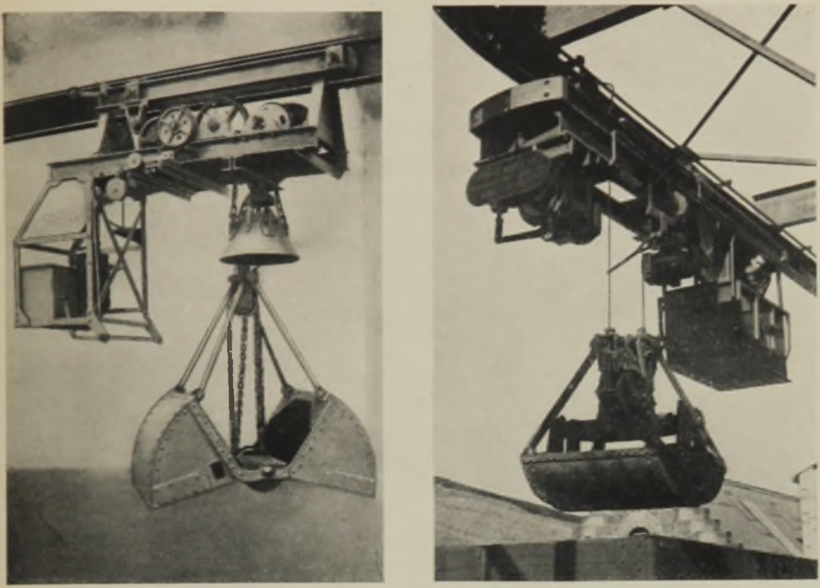
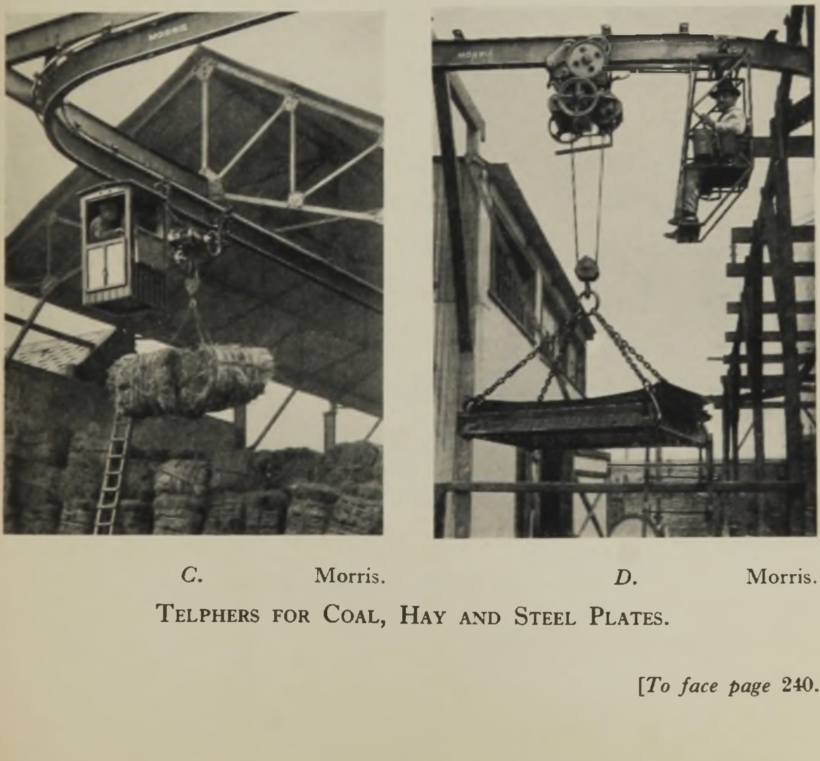


FIG. 139.—Diagram of Toplis Rope-luffing Gear for Heavy Cranes.

represents the energy consumed by the luffing motor of a non-compensated crane while engaged in luffing a load of



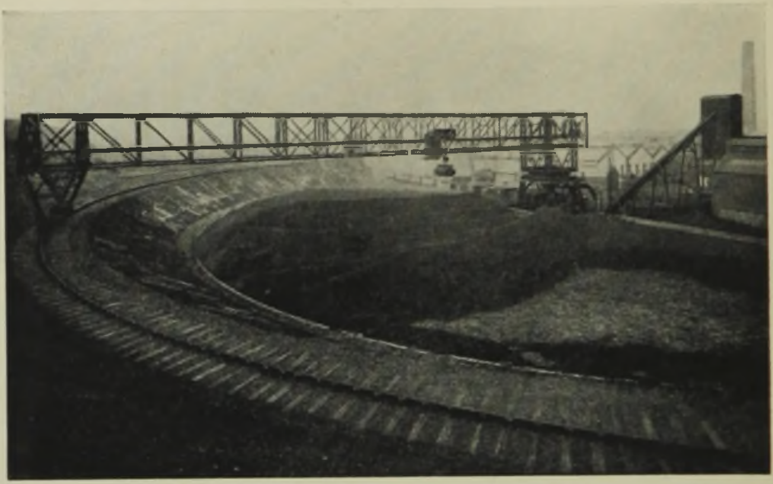
A. Babcock. *B.* Morris.



C. Morris. *D.* Morris.

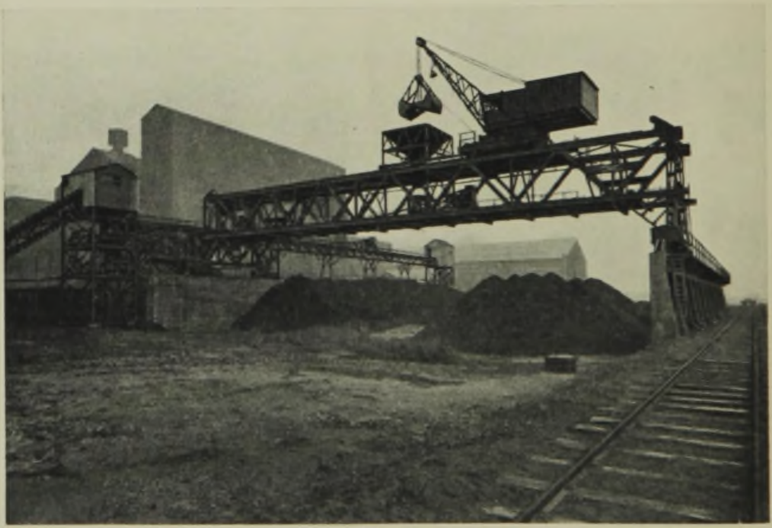
TELPHERS FOR COAL, HAY AND STEEL PLATES.

[*To face page* 240.



Babcock & Wilcox Ltd.

A.—2-TON RADIAL TRANSPORTER.



Babcock & Wilcox Ltd.

B.—4½-TON TRANSPORTER CRANE.

Brown Hoisting Machinery Co.

4-ton Bridge Transporter.

PLATE 38

SIMPLE TRANSPORTER INSIDE WAREHOUSE.

Herbert Morris Ltd.

OUTSIDE VIEW OF SIMPLE TRANSPORTER.

To face page 241.]

3 tons from 46 to 22 ft. radius. By contrast the small black area shows the consumption of energy by the luffing motor of a Toplis crane while performing the same duty. The great difference in these two areas represents the marked saving in energy by utilizing level-luffing gear.

Adaptation to Heavy Cranes.—The modification of the Toplis rope-luffing gear diagrammed in Fig. 139 is better adapted for cranes of large capacity than for ordinary quay cranes. It is applicable to cranes lifting heavy loads on bottom blocks with two or more falls of rope. The ropes, however, are both long and numerous, and this complication is a bad feature. Better designs are now available.

On tracing the path of the ropes it will be seen that the single-hoisting rope has one end anchored to the luffing barrel and the other end to the hoisting drum. From the latter the rope passes over a mast-head sheave, then over a jib-head sheave, then around a bottom-block sheave, then upwards and around a second jib-head sheave, then on to and around a second mast-head sheave and lastly down to the luffing barrel, which is geared to the hoisting drum.

On luffing in the jib the luffing barrel pays out the hoisting rope in the exact amount needed to keep the load moving horizontally. The luffing ropes are in pairs, winding around the smaller ends of the special luffing drum, the middle part of which is of larger diameter.

Tracing one dotted luffing rope from its anchorage at the jib head, it passes over one mast-head sheave, then around the small end of the barrel, then up and over a balance sheave and finally down to the weight. As the jib is balanced at all radii with *any load*, high speeds can be attained with a small expenditure of power.

An example of a 10-ton level-luffing rope-operated crane made by Sir William Arrol & Co. Ltd. is depicted on Plate 30. It can handle 10 tons at a maximum radius of 49 ft. (equal to a moment of 490 ton-ft.). This double-portal crane was installed by the Port of London Authority at the West India Docks for handling big logs. The complexity of the rope-luffing gear is obvious.

CHAPTER XX

HEAVY COALING AND WHARF CRANES

At every important port it is necessary to provide several big cranes capable of loading large quantities of coal and heavy cargo like boilers and machinery. A good example of such a crane is well illustrated by the photographic view on Plate 34. The roller turntable below the massive superstructure is well seen. As a derricking motion is fitted, less use need be made of the travelling motion than in a fixed-radius crane.

35-ton Electric Coaling Crane.—An example of a fixed radius coaling crane, also made by Babcock & Wilcox Ltd., is erected at North Quay, Queen's Dock, belonging to the Clyde Navigation Trust. A full account of it was given in a paper by Daniel Fife, read in 1923 before the Institution of Mechanical Engineers at Glasgow, from which has been adapted Fig. 140, illustrating the general arrangement of this fine double-portal crane.

The greatest working load in this case is 35 tons at a fixed radius of 57 ft., representing a tipping moment of, say, 2000 ton-ft. The total weight of the crane, complete with 66 tons of back ballast, is 315 tons. Some other technical data are tabulated below :—

Total range of lift of block for general cargo	110 ft.
Total range of lift of block for coaling	80 ,,
Centre of jib head above coping of quay	103·5 ft.
Clear lift above coping to bottom of cradle	65 ,,
Lifting speed with load of 32 tons	50 ft. per min.
Slewing speed with load of 32 tons	450 ,,
Travelling speed with load of 32 tons	60 ,,
Factor of safety for structure and gearing	7·5
Factor of safety for hoisting and tipping ropes	8

The *gantry* carrying the crane is of the portal type with a clear vertical height of 15 ft. and a span of 30 ft. between the rails. It is supported on sixteen cast-steel wheels, 30 in.

diameter on the tread, which are mounted on compensating bogies to ensure the weight being equally distributed on the wheels.

The upper part of the gantry is provided with deep beams and transverse girders for supporting the roller path and the centre pin. The lower roller path is a ring of cast steel 27 ft. mean diameter by 12 in. broad, on which the revolving structure is supported by sixty-four live rollers of 14 in.

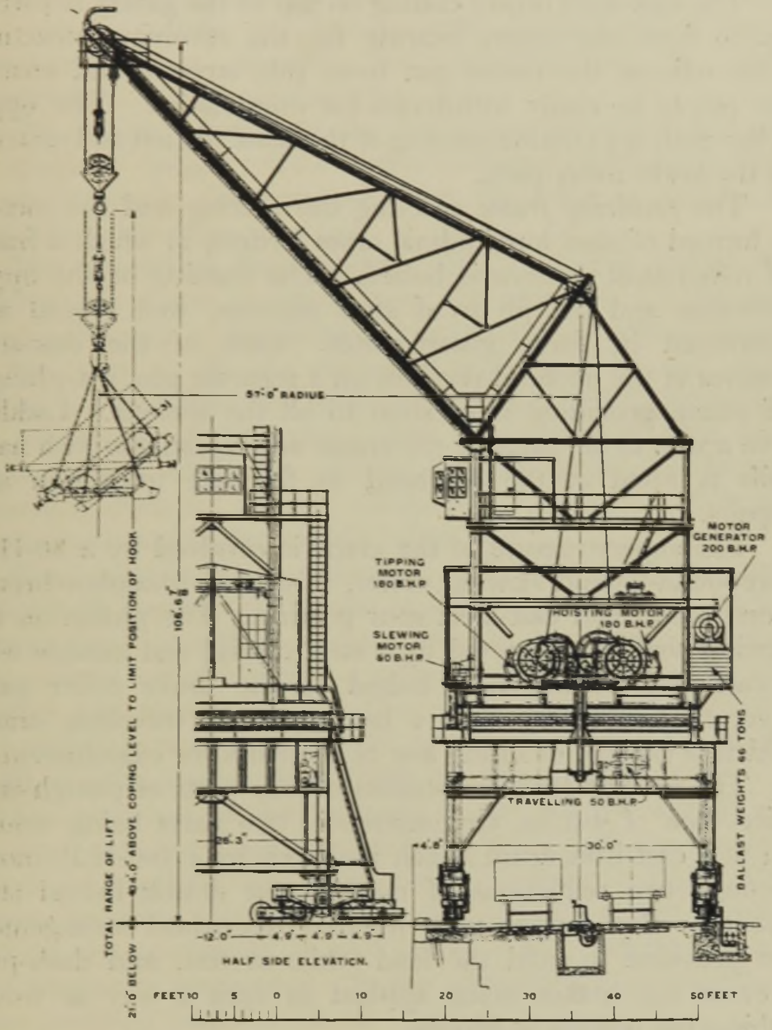


FIG. 140.—35-ton Electric Coaling Crane.

maximum diameter. These rollers are carried by a spider ring connected to a centre casting, while gun-metal washer plates are fitted for taking up the end pressure on the outer ring, each roller being fitted with a lubricator.

The cast-steel centre casting on top of the gantry is carried up to form the centre bearing for the revolving structure. This relieves the centre pin from side stresses and enables the pin to be easily withdrawn for examination. The upper roller path is a continuous ring of the same section and material as the lower roller path.

The *revolving frame* carrying the gearing and the motors is formed of steel longitudinal cross girders, to which a frame of rolled-steel sections is bolted. The framing of the upper structure and the jib is of steel sections, well braced and connected by large gusset-plates. Each of the cast-steel sheaves at the jib head revolves on a separate pin, a 4-plunger oil pump providing lubrication to all the sheaves. Ladders give access to all parts of the crane, and a platform with hand rails is fitted at the jib head to facilitate inspection and repairs.

The superstructure of the crane is revolved by a 50-H.P. compound-wound slewing motor, through a phosphor-bronze worm-wheel and cast-steel spur gearing. The pinion on the vertical shaft is supported by a steel casting and meshes with a cast-steel slewing rack bolted to the lower roller path. Over the machinery runs a hand-operated travelling crane, which is capable of lifting any of the parts for examination.

The *hoisting purchase* consists of four parts of plough-steel wire rope of 4·3 in. circumference, two parts being wound on to a cast-iron drum which is driven by a 180-H.P. motor through two reductions of machine-cut double-helical steel gearing. Post brakes with internal free-wheel arrangement are provided to hold the load while at rest, and dash-pots prevent the brakes being applied in such a way as would subject the gearing to shocks.

The *tipping rope* consists of two parts of plough-steel wire rope of 4 in. circumference, with a return block to which are secured the tipping chains of the wagon cradle. One end of this rope is fastened to a barrel in the machinery house, which is actuated by a pinion meshing with the main spur-wheel on the hoisting drum, thereby taking up the slack tipping rope when hoisting the cradle. The other end of the tipping rope is actuated by a barrel driven in the same manner as the hoisting gear by a motor of the same power. The brake provided is of similar design to the hoisting-gear brake.

When working ordinary cargo the tipping-block is hoisted to a suitable height, the holding brake applied and a clutch disengaged, thus allowing the hoisting-block to work independently of the tipping gear.

The *coaling cradle* is of the Armstrong through type, and is capable of dealing with a wagon containing 20 tons of coal. It can be easily disconnected when the crane is needed to deal with loads other than coal.

The Electrical Equipment.—The electrical energy for driving this crane is taken from the Glasgow Corporation mains, through a switch-house for supplying *direct current* at 500 volts to all the electrical appliances on the quay. Cables are laid from the switch-house to a trench extending the full length of the crane travel. This contains bare conductors, from which the current is collected by double-arm swivelling trolleys. Supply cables pass through a centre pin to a switchboard in the control cabin.

The switchboard is equipped with circuit-breakers and switches to control the circuits to the motor generator, to the slewing and travelling motors and to the crane lighting. The control cabin contains a potentiometer regulator for the *hoisting* and *tipping* motors, also controllers for the slewing and travelling motors, as well as indicators showing the height of lift and the tipping angle of the wagon.

The electrical method adopted to operate and control the hoisting and the tipping motors is the Crompton system, which is a modified form of the Ward-Leonard control. This system provides a safe, accurate and efficient means of controlling the operations of the crane, when handling either coal wagons or machinery. It also obviates the use of brakes when lowering loads.

In order to supply direct current at 500 volts to the motors, a motor-generator of 200 H.P. is installed in the machinery house. This comprises two direct-current machines running at a speed of 680 revs. per min., coupled together and mounted on a cast-iron bedplate. The motor end of the combination is a standard shunt-wound machine, provided with interpoles and designed to withstand rapid fluctuations of load without sparking.

The generator or dynamo, however, is of the variable-voltage type with separately excited field magnets. As this dynamo runs at a constant speed, its voltage is always in direct proportion to the field strength. The speed in both directions of the hoisting and the tipping motors is controlled by varying from maximum to minimum the strength of the shunt current in the dynamo field magnets, and by reversing the direction of the current.

A reversing-type potentiometer regulator, operated by the driver, controls the shunt-current. This regulator has a large number of contacts, which makes the control very sensitive by varying the volts upward or downward, according to the position of the control lever when hoisting or lowering. In addition to the shunt-winding on the field coils of the dynamo, a special limit series-winding is embodied. This *series*-winding carries the main current generated and is wound in the reverse direction to the *shunt*-winding. It thus opposes the latter and tends to weaken its magneto-motive force, the total magnetic flux being the resultant of the two windings.

This *differential field-winding* has valuable safeguarding features, in preventing the operator exceeding a predetermined speed of hoisting or otherwise overloading the machinery. It is possible to throw the control lever into the full-speed position for hoisting, lowering or tipping, without causing an excessive current to flow through the motor ; since the limit winding prevents too rapid a rise of the dynamo voltage and therefore does not allow the motor to accelerate too quickly. The motor is so wound that its speed is proportional to the dynamo voltage applied across its armature terminals.

The hoisting and the tipping *motors* are duplicates, each developing 180 H.P. at the maximum speed of 400 revs. per min. The armatures of these machines have no special features, but the *field*-winding is compound-wound, which is more economical in field watts than a pure shunt-winding would be when the motor is standing. The shunt-winding is connected across the incoming 500-volt supply, and is excited from special contacts on the starter from the motor-generator. Thus the shunt-current on the motors remains constant whenever the dynamo is running.

The *series* field-windings consist of a few turns of heavy wire. The magneto-motive force is thus proportional to the input current to the motor generator, and therefore varies as the load on the hoisting or the tipping motor. These heavy series turns increase the *torque* of the motor in proportion to the load being lifted. Being connected to the incoming supply of current, there is no need to reverse the series-winding when the current to the armature is reversed. As the shunt field remains constant, the speed of the hoisting or of the tipping motor is practically dependent on the voltage across the armature.

If there were no *series* field turns, the speed would be directly proportional to the applied voltage, but these heavy windings tend slightly to decrease the speed of the motor when the load is at a maximum. The torque exerted by the motor is proportional to its field strength multiplied by the armature current, and sufficient forward current can be applied to the armature to exert the requisite torque for sustaining the full load.

On the hoisting and tipping gears are provided shunt-wound *solenoid brakes* with dash-pots. They are operated by a change-over switch and so arranged that the brakes are applied when the current to the motors is insufficient to sustain the load and are released when the motor current becomes strong enough to lift the load. This reduces the wear of the brakes to a minimum. This is proved by the fact that in a crane similarly equipped the original brake linings were still in use, after loading 2½ million tons of coal over a period of seven years.

When lowering a load the necessary braking action is accomplished by *regeneration*, a method by which the generated voltage is reduced by the operator through the potentiometer to a value below the volts generated by the hoisting motor when being driven by the falling load, and therefore running as a generator. Under these conditions current passes from the hoisting motor back through the motor-generator set to the supply mains.

This system gives smooth and effective retardation of the load, and creeping speeds can be obtained when hoisting or lowering. It is almost impossible to cause damage to the electrical gear by faulty handling of the controller, as no special skill is required by the operator.

The diagram (Fig. 141) refers to the performance of a similar coaling crane at Queen's Dock. It records the amperes and the voltage of the current during a complete cycle of operations, namely, hoisting, slewing, tipping and lowering a truck loaded with coal, the period of the cycle being 2·4 min. The gross load here amounts to 24 tons. This diagram graphically shows in full lines the current absorbed in hoisting and tipping, also the energy returned to the line by the descending load. The dotted line refers to the voltage.

The power generated by the falling load cannot all be taken as useful, because the loss due to the inefficiency of the motors and of the motor-generator has to be made up before any current can be returned to the Corporation mains. From meter readings taken over several years of actual working, it appears that the energy credited by the Electricity Department amounts to 8 per cent. of the total current taken.

The following table gives the efficiency of one of the electric coaling cranes taken under test conditions :—

EFFICIENCY TESTS

Weight	Height	Time	Power Readings		Calculated Horse-power		Efficiency
Tons	Ft.	Secs.	Volts	Amps.	Load	Electric	Per cent.
32	50	40	490	365	163	240	67·5
24	50	37	495	280	132	186	71
17·15	50	35	500	220	100	147	67·7

In the original paper already referred to, Mr Fife gives several examples of the actual performance of this crane when loading coal into bunkers, the average lift being about 30 ft. In one case 1490 tons were loaded in 6 hours at the rate of 248 tons per hour. In another case 7040 tons of coal were loaded in 45½ hours at the average rate of 155 tons per hour. These figures represent the best and the worst performances.

Taken over the year 1922, the detail working costs of

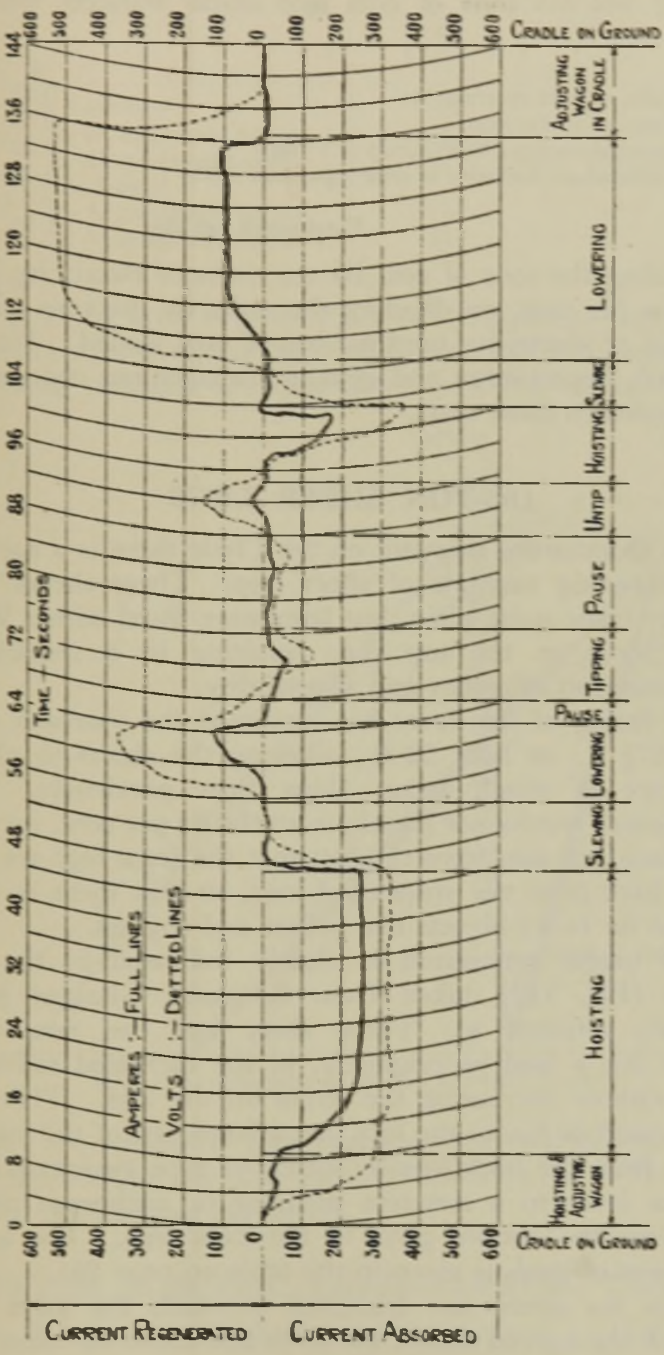


Fig. 141.—Curve showing a Complete Cycle of Operations.

shipping 464,255 tons of coal into ships' bunkers were as follows :—

	d.
Wages of men on crane	0·23
Wages of cradle men	0·52
Electrical energy (88,985 units at 1·13d.) . . .	0·22
Maintenance, inclusive of wire ropes and stores . .	0·26
Total pence per ton .	1·23

Dividing the tons of coal by the units of electricity gives 5·21 tons per unit, on dividing the units by the tons we get 0·19 unit of electricity used per ton of coal loaded. Interest on capital, depreciation and general management charges are not included in these costs.

100-TON SHEER LEGS

At a Dumbarton shipyard on the Clyde there is a particularly interesting example of sheer legs. These sheers were originally made quite plain, but later were fitted with a Wylie folding lever on the top pin, resulting in a remarkable improvement in efficiency and adaptability.

The fitting of this lever has increased the outreach from 35½ to 57½ ft., or fully 22 ft., allowing the sheers to plumb the centre of much larger ships than previously. This improvement results not merely from the 60 per cent. increase of outreach but also from the fact that the front legs are now further back from the suspended load, so that there is more clearance for bulky objects like boilers and engines.

This useful conversion is clearly indicated in the line diagram (Fig. 142), taken from Kemnal's Glasgow paper previously referred to. These sheer legs can now carry quite as big a load as originally, at the increased radius of 22 ft., without increasing the stress on the legs. This surprising result is due to the fact that a large part of the loading is taken from the back legs by means of rope guys extending from the lever to a concrete mooring or anchorage placed 90 ft. from the bottom pivot of the front legs. The actual comparison of loads is given in the table on page 251.

When the sheers are traversed outwards the guys now hold back the curved end of the lever and cause the other end carrying the load to move outward in an upward sloping path.

	With Lever	Without Lever
On *front* leg—	Tons	Tons
A. At maximum radius .	234	235
B. At minimum radius .	157	142
On *back* leg—		
C. At maximum radius .	12	93
D. At minimum radius .	24	23

The Wylie lever is further pivoted on a sort of centre-post, thus allowing it to deflect sideways in the event of the suspended load being dragged to either side, by which means twisting stresses are avoided. This ingenious conversion was carried out expeditiously by the firm of Babcock & Wilcox Ltd. without dismantling the sheers.

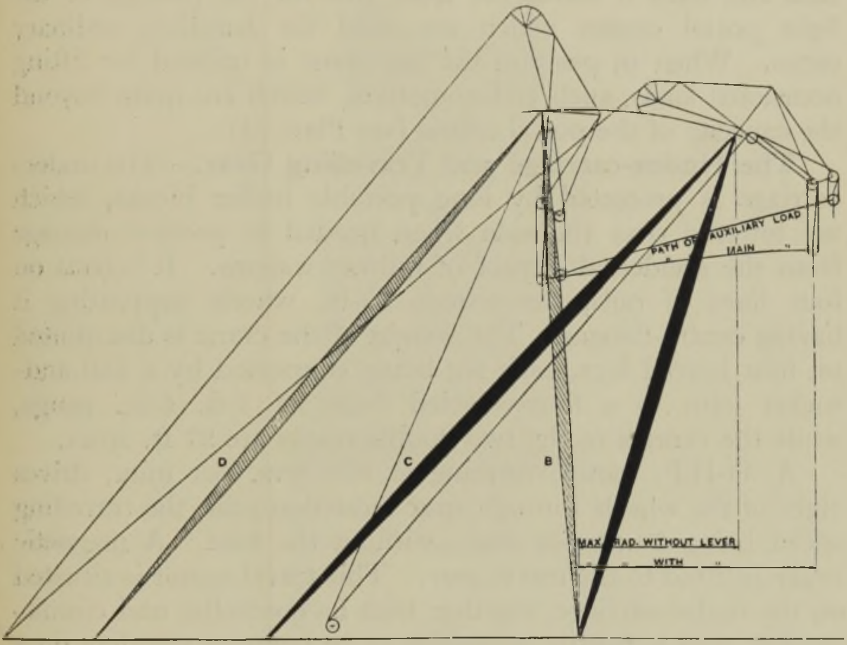


FIG. 142.—Diagram of Sheer Legs with Lever.

80-TON ELECTRIC LEVEL-LUFFING CRANE

In the year 1933 there was constructed by Babcock & Wilcox Ltd., and erected on the wharf at Durban, for the

South African Railways and Harbours Administration, an unusual crane[1] of special technical interest as being the largest of its particular type ever made. The maximum capacity of this useful wharf crane is 80 tons at a radius of 62½ ft., giving a moment of 5000 ton-ft., and it is equipped with an auxiliary lift of 20 tons at 72½ ft. radius. All the motions are operated electrically.

The crane in question was described in *Engineering* of October 6th, 1933, from which account the drawing (Fig. 143) has been taken. It is not a portal crane, as it is run back from the water's edge when not in use, the travel motion taking place on a track laid at right angles to the quay wall. When thus run back it leaves the quay free for the passage of the light portal cranes which are used for handling ordinary cargo. When in position the big crane is utilized for lifting occasional loads, such as locomotives, which are quite beyond the capacity of the portal cranes (see Plate 34).

The Under-carriage and Travelling Gear.—The under-carriage is protected by long portable buffer blocks, which are lowered over the side when needed to prevent damage from the accidental impact of railway wagons. It travels on four lines of rails, the sixteen 33-in. wheels supporting it having centre-flanges. The weight of the crane is distributed on four braced legs, each leg being connected by a ball-and-socket joint to a four-wheeled bogie of 3-ft. 6-in. gauge, while the centres of the two double tracks are 27 ft. apart.

A 35-H.P. motor, running at 650 revs. per min., drives eight of the wheels through spur reduction gear, the travelling speed being 30 ft. per min., without the load. A magnetic brake is fitted to the travel gear. This travel motor is situated on the under-carriage, together with its controller and circuit-breaker, and is readily accessible to an operator standing on a platform close to the ground. In order to anchor the crane firmly in position at each end of its travel of 53 ft., links and shackles between the bogies are provided, which engage with hooks bedded in the concrete foundation.

The Slewing Gear.—The top of the under-carriage carries the roller-path or race and a fixed slewing rack which is built up of steel sections. The rack teeth consist of

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[1] When visiting Natal in the spring of 1935 I had the pleasure of inspecting this noteworthy wharf crane, which is a job to be proud of.

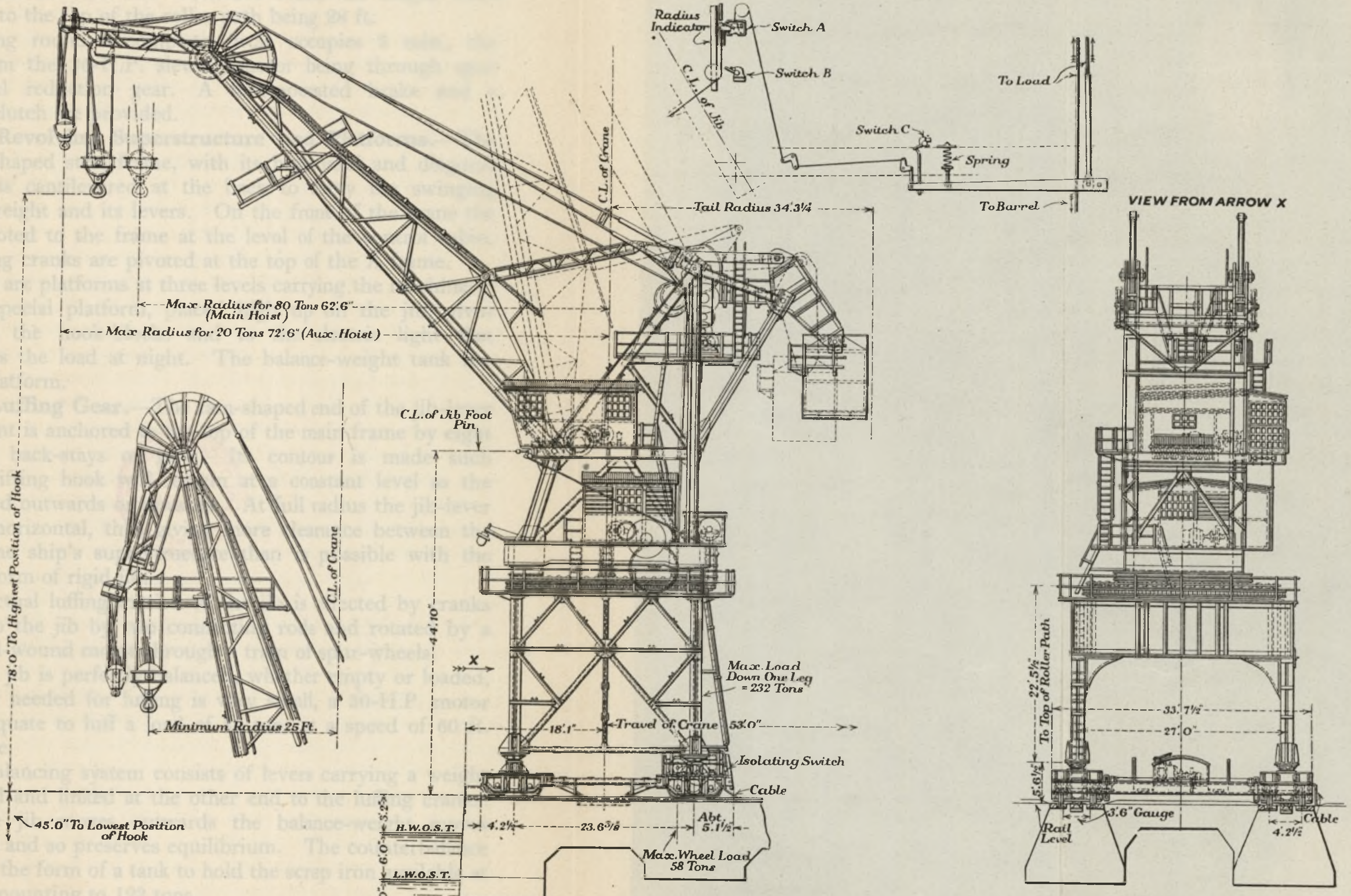

FIG. 143.—General Drawing of 80-ton Electric Wharf Crane.

[*To face page* 252.

renewable rollers on high-tensile steel pins. A ring of live rollers runs between two machined races, the height from rail level to the top of the roller path being 28 ft.

Slewing round a complete circle occupies 3 min., the drive from the 35-H.P. slewing motor being through spur and bevel reduction gear. A foot-operated brake and a slipping clutch are provided.

The Revolving Superstructure and Platforms.—The main A-shaped steel frame, with its horizontal and diagonal bracing, is cantilevered at the back to carry the swinging balance weight and its levers. On the front of the crane the jib is pivoted to the frame at the level of the control cabin. The luffing cranks are pivoted at the top of the A frame.

There are platforms at three levels carrying the machinery, while a special platform, placed high up on the jib, gives access to the hook-blocks and to the electric light that illuminates the load at night. The balance-weight tank has its own platform.

The Luffing Gear.—The cam-shaped end of the jib-lever or quadrant is anchored to the top of the main frame by eight wire-rope back-stays or guys. Its contour is made such that the lifting hook will remain at a constant level as the jib is luffed outwards or inwards. At full radius the jib-lever becomes horizontal, thus giving more clearance between the jib and the ship's superstructure than is possible with the ordinary form of rigid jib.

The actual luffing motion of the jib is effected by cranks coupled to the jib by two connecting rods and rotated by a compound-wound motor through a train of spur-wheels.

As the jib is perfectly balanced, whether empty or loaded, the power needed for luffing is very small, a 30-H.P. motor being adequate to luff a load of 80 tons at a speed of 60 ft. per minute.

The balancing system consists of levers carrying a weight at one end and linked at the other end to the luffing cranks. When the jib moves outwards the balance-weight moves backwards and so preserves equilibrium. The counterbalance here takes the form of a tank to hold the scrap iron available at the site, amounting to 123 tons.

In action this Wylie level-luffing gear works smoothly and rapidly. As regards durability, if the guys are effectively protected from the weather the wear on them in contact with the lever curves is negligible, since they are not running ropes. The hoisting rope also is at rest during the luffing period. Consequently renewals are infrequent.

The uniform rotation of the luffing cranks imparts *harmonic motion* to the jib, thus automatically slowing down the speed of luffing as the limits of travel are approached and diminishing the inertia shocks.

Safety is attained by the use of automatic *limit switches* which cut off the supply of current to the luffing motor when the full radius of 72½ ft. with a 20-ton load or a minimum radius of 25 ft. has been reached.

The Stability of the Crane.—The position of the centre of gravity of the jib with its counterbalance system changes somewhat for the various positions of the jib, but not nearly so much as it would if fixed ballast at the back of the crane were adopted. The centre of gravity, however, remains well within the roller path under all conditions of working, thus equalizing the load on the rail wheels. Moreover, the crane has been designed to be quite stable when in an unloaded state and subjected to a wind pressure of 40 lb. per sq. ft.

The Hoisting Motion.—The full load of 80 tons can be raised at the rate of 5·75 ft. per min., or half that load at double the speed by using a change-speed gear. In each case the gravity horse-power is the same and is equal to

$$80 \times 5{\cdot}75 \times 2240 \div 33{,}000, \text{ or } 31 \text{ H.P.}$$

Actually, however, the motors provided for both the main and the auxiliary lifts are each of 50 H.P. They are series-wound and make 600 turns per minute.

The main hoisting rope passes over a series of sheaves on the jib-lever and through the main return-block in *ten* falls of rope. It winds on to a grooved hoisting drum of welded steel construction, measuring 6 ft. in diameter and no less than 11·5 ft. in length. The main hoist spur-wheel and its pinion are machined from mild steel blanks. When in its highest position the hook is 78 ft. above the wharf level, and it may be lowered to a depth of 45 ft. below that level. Thus the total lift is no less than 123 ft.

Housed on the middle platform beside the operator's cabin is the *auxiliary* hoisting winch, which will lift 20 tons at a speed of 24 ft. per min., or alternatively half that load at double the speed. The auxiliary return-block has *six* falls of rope.

The main hoisting and the slewing machinery, however, are housed on the *bottom* platform just above the roller-path. The control cabin is on the *middle* platform, placed 44 ft. above the quay level. It has a projecting window, giving a clear view of the load under all conditions. This cabin contains all the control gear for the hoisting, the luffing and the slewing motors.

Overload Protection is secured by an ingenious device which prevents loads exceeding 80 tons being lifted and also prevents the radius exceeding 62½ ft. with this load on the hook.

This over-loading and over-luffing protection device is diagrammed above the general drawing. The position of the jib is shown at any point by a radius indicator. At maximum radius it operates switch A and at minimum radius switch B. Coupled to switch A by an operating lever is another switch C, thus preventing an overload at maximum radius.

The Control Gear comprises four tramway-type reversing controllers and resistances, also a relay panel fitted with a main double-pole contactor and with double-pole relays for protecting the three motors on the revolving superstructure, as well as the levers for operating the mechanical brakes. In addition to the latter, each of the hoist controllers has dynamic braking on the *lowering* side, while the hoist motors are equipped with automatic magnetic brakes.

All the motors, save the luffing motor, are *series*-wound and are totally enclosed, the exception being *compound*-wound. Direct current at 550 volts is brought to the crane by a flexible trailing cable 60 ft. long, with a plug fitting into either of two plug boxes near the crane track on the wharf at Durban.

CHAPTER XXI

ELECTRIC RUNWAYS, TELPHERS AND TRANSPORTERS

Terminology.—There is considerable slackness and elasticity in respect of the terminology of the machines that form the subject of this chapter, the usage differing according to time and place. Unfortunately there is no systematic nomenclature and classification of lifting and moving appliances in general corresponding to the exact terminology of such sciences as chemistry, biology, botany and geology.

Some engineering terms are peculiar to certain localities or are used in different senses in different parts of the world, especially if we include North America in our survey. For instance, the American *boom* is our familiar English *jib*, while the common term *crab* is hardly there used at all. The term *gantry* is employed in a variety of senses.

What is nowadays styled as ‘ telpher ’ [1] used to be called a ‘ transporter.’ It is still so called by some users and by others a ‘ conveyor.’ Also a light Goliath crane of long span with extended cantilever ends is termed a transporter by some and a bridge crane or a transporter crane by others.

At various times in different publications one meets with such terms as electric trolley hoist, suspension crane, electric runway, electric transporter, telpher, telpher transporter, electric monorail hoist and trolley-hoist bridge transporter. All these terms are used more or less indifferently or synonymously to denote a light travelling carriage suspended from a single joist track, either self-propelled by a motor or hauled along by a rope, the track being supported in various ways. The travelling transporters mounted on wheels are broadly divided into three types, viz., cantilever tower, bridge and radial, according to the general layout.

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[1] Derived from the Greek words *tele*, meaning ‘ far ’ and *phero*, meaning ‘ to carry.’

A.—GROUP OF ROPE TROLLEY TRANSPORTERS.

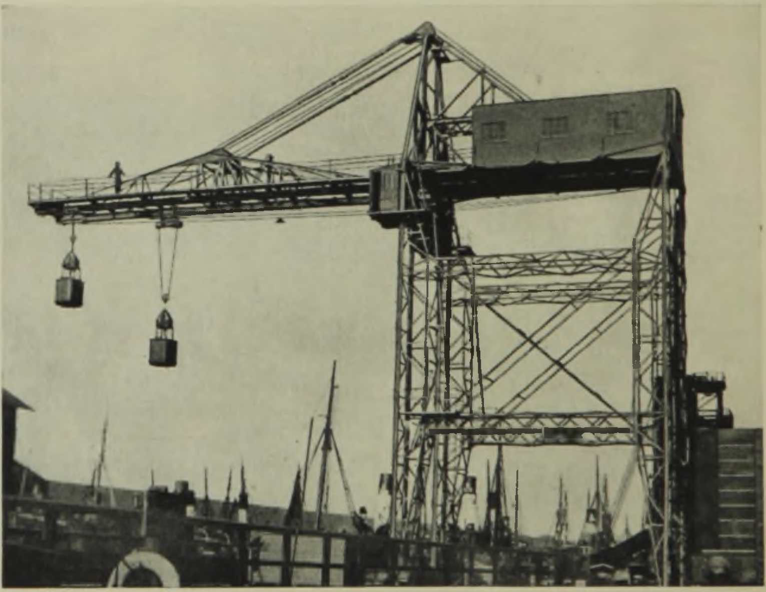
Ransomes & Rapier Ltd.

B.—TRANSPORTER ON ROOF OF SUGAR STORE.

[*To face page* 256.

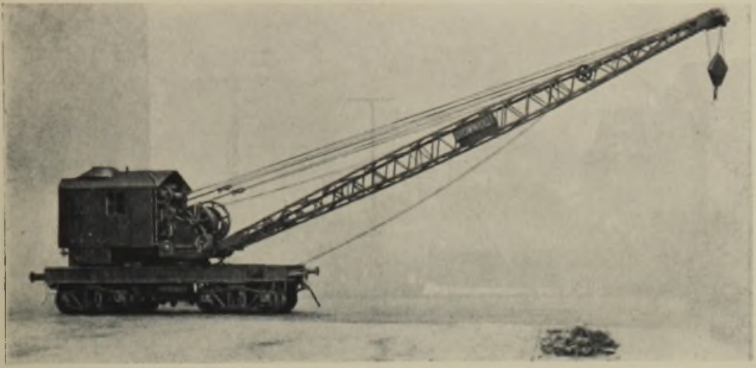
Sir William Arrol & Co. Ltd.

A.—TEMPERLEY COAL TRANSPORTER AT PORTSMOUTH.

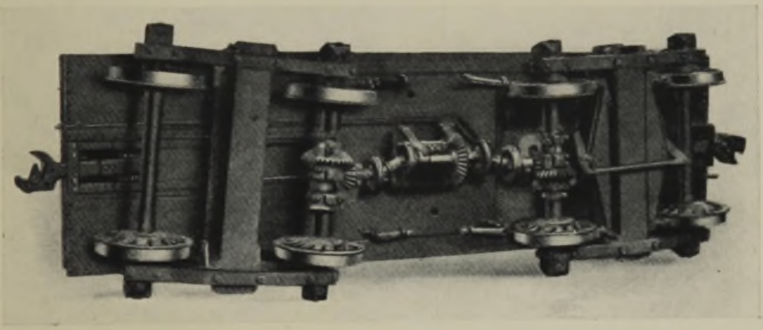


Ransomes & Rapier Ltd.

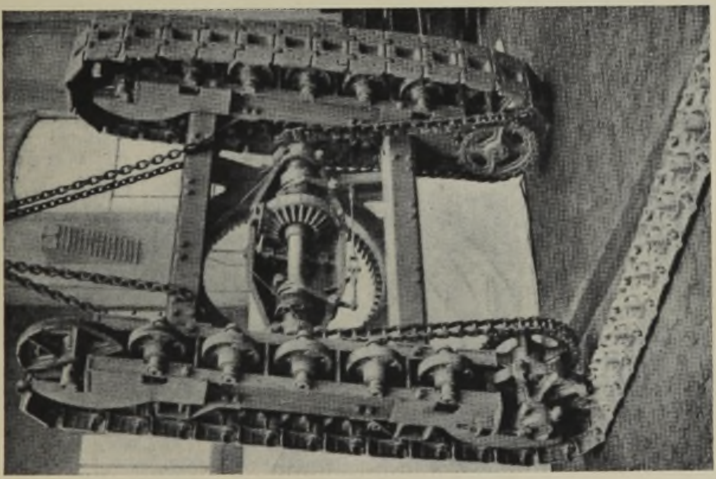
B.—DOUBLE COALING TRANSPORTER AT HULL.



“ BROWNHOIST ” LOCOMOTIVE CRANE.

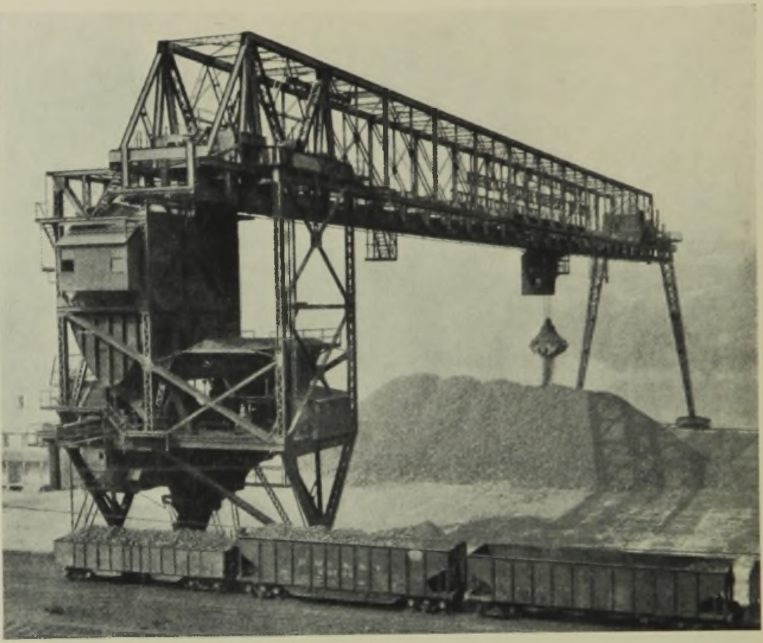


UNDERSIDE OF LOCOMOTIVE CRANE.

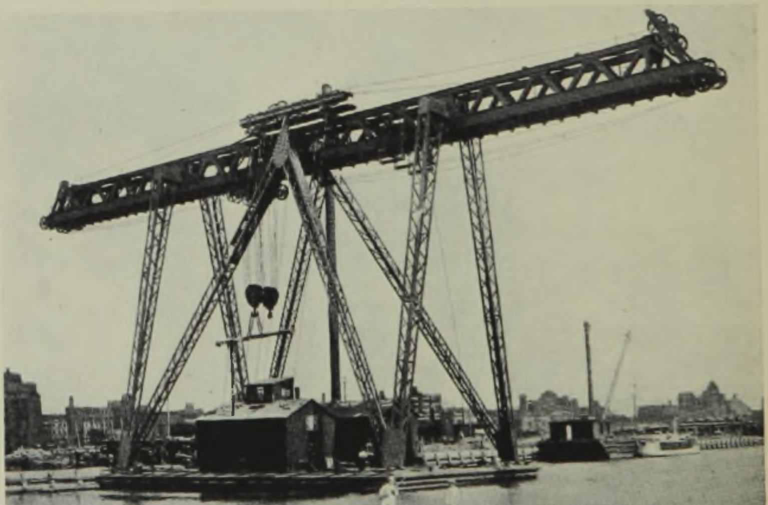


Ruston-Bucyrus Ltd., Lincoln.

CATERPILLAR TRACKS FOR EXCAVATOR.



A.—"BROWNHOIST" COALING BRIDGE.



Industrial Brownhoist Corp., Bay City, U.S.A.

B.—100-TON PONTOON CRANE.

To face page 257.]

One important point of distinction is that in all telpher systems proper the carriage is self-driven by a motor and gearing, and is usually controlled by a man riding on it. Yet the complete carriage is not called a ‘ crab ’ but a ‘ man-trolley ’ or a ‘ telpher machine.’ In a transporter crane, however, the carriage is frequently hauled along by a wire rope, in which case it may be correctly styled a ‘ trolley ’ or a ‘ jenny ’ or a ‘ traveller.’

The essential feature of a transporter seems to be a straight beam forming a horizontal or slightly inclined track, along which runs to and fro a trolley from which the load is suspended. The load is always rather light, ranging from 1 to 3 tons. It is difficult to draw a precise distinction between a cantilever tower crane, as used in shipbuilding, and a tower-type transporter, save that a tower crane is always taller and heavier than a transporter and the trolley runs on a double track.

A fixed telpher is not really a transporter, though some people call it so. Often a transporter consists of a straight-run telpher *mounted on wheels.* Etymologically speaking there is no difference between a transporter and a conveyor. Technically, however, there is a good deal of difference, the one involving the idea of a to and fro motion and the other of a *continuous* motion in one direction.

A telpher *track* may be of any length, straight or curved, rounded-rectangular, circular or otherwise and forming a closed circuit.[1] Also, there may be several carriages or telpher machines on one track, not interfering with one another. On the other hand a transporter has but one trolley.

Many transporters and many telphers are used in conjunction with grabs for unloading coal from barges and ships and delivering it into coal stores at ground level, or into elevated hoppers at electric power stations. Other telphers handle coke in skips from retort-houses to storage heaps in gasworks.

A telpher machine is really a special form of electric crane without any cross-traverse motion. It usually runs on a single-joist overhead track, containing several bends and junctions. The earliest example of a rigid electric runway was made about the year 1890 at Victoria Station, Manchester,

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[1] A good example is illustrated in the description of Norwich Power Station contained in *The Engineer* of March 11th, 1938.

by its inventor, Sir John F. Aspinall, who was then chief mechanical engineer of the old Lancashire & Yorkshire Railway Co. This early machine took wicker skips filled with parcels across the various platforms and tracks, being worked by a lad who sat beneath it.

The Aspinall telpher differs from more recent examples in having a *double track*, the current passing along one track and returning along the other. There is no overhead wire and no trolley pole, as used with modern telphers. A similar machine was exhibited in operation by the author on Mather & Platt's stand in the Machinery Hall of the Glasgow International Exhibition of 1901. Since that date great improvements have been made in the design of telphers, and they have long been recognised as very serviceable and convenient labour-aiding appliances.

A complete *telpherage system* comprises three main divisions, namely (1) the *track*, which is usually fixed at a high level, (2) the self-propelled *winch* that travels on the track, and (3) the copper or other metallic *conductors* which transmit the electric current to the operating motors.

Strictly speaking the name *telpher* refers to the entire installation or telpherage system, though it is often applied to the travelling winch only, for the sake of brevity, instead of always saying the ' telpher machine ' or the ' electric trolley hoist.'

Whilst it would be hardly correct to say that the telpher has evolved from the simple hand runway with its pulley-block through the hand-propelled electric trolley hoist, yet certain features of the modern telpher are no doubt due to its association with these simpler forms and with the more complex trolley hoist equipped with power travelling gear. The latter, in later designs, bears a strong family resemblance to the bigger and faster telpher machine.

Telpher Machines.—Telphers have been constructed for handling grabs and skips containing coal, coke, ashes, ore, barrels, bags and cases. Plate 35 (A) depicts a telpher machine with a rigid wheel-base for a straight track, equipped with a single motor. It runs on the bottom flange of a joist and carries a single-chain ring-operated grab for coal. For heavy duty the travelling wheels should run on a rail carried by the top flange of the joist. B, C and D show further applications.

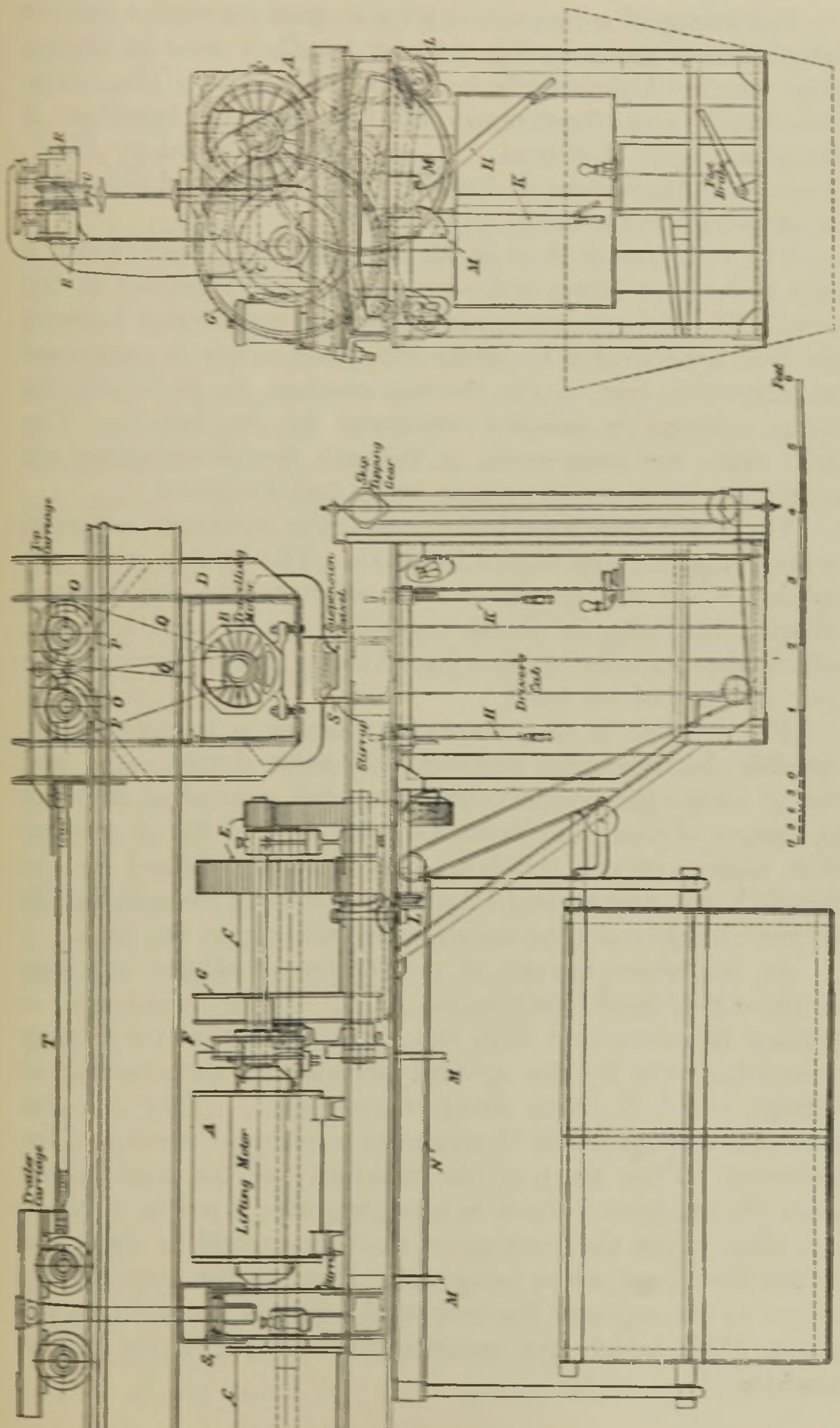

FIG. 144.—Heavy Type of Telpher Machine for Coke.

A drawing of a two-motor telpher machine with a flexible wheel-base is given in Fig. 144 for handling coke in tipping skips at the Dalmarnock Gasworks, Glasgow. The entire installation was constructed by the firm of Strachan & Henshaw Ltd., of Bristol. It was fully described by G. F. Zimmer in *Engineering* of February 16th, 1917, and illustrated by drawings and photographic views.

The hoist motor A is of 35 H.P. and the travel motor B of 8 H.P., both being series-wound for direct current at 500 volts. The hoist motor is carried on the main frame between the two hoist drums C, while the travel motor is supported on adjustable feet in the driving carriage D, to which the trailer carriage is flexibly connected by the link L. The drive from the hoist motor is through double-reduction cut spur gears of steel, the pinions being case-hardened.

There are two hoist brakes, viz., the automatic solenoid brake F and the free-barrel brake G. The former is at once applied when the current is cut off from the hoist motor, whereas the latter brake is controlled by a hand lever H, which also actuates a safety interlocking device between the gear-release and the brake.

The purpose of this interlocking device is to prevent any possible disconnection between the hoist drums, gear and motor before the operator has taken full control of the load by means of the hand brake G. As soon as the drums are thus under control, the hoist gear may be released by the handle K and bevel wheel L, and the load then lowered rapidly on the hand brake, thus saving wear and tear on the gears.

An important feature of this design of telpher machine is the safety-hook mechanism MM. These hooks are so pivoted in connection with the hand brake that they swing outwards freely by the upward pressure of the crossbar or lifting ‘ bale ’ N, with which they engage. They are also caused to swing clear of N when the hand brake is released for lowering. Thus there is no possibility of the load falling from the machine while it is travelling over a public street or any place where the breakage of the ropes would be disastrous in the absence of some safeguard. Here, in the event of any failure of the ropes or the brakes, the bale N is caught on the hooks MM, which are securely fixed in the frame of the machine.

The travelling wheels O on the top of the carriage are driven from the motor below by the sprocket wheels P and the two roller chains Q. This method ensured a good grip and a longer life than a single-chain drive gives. The track wheels are made of manganese steel and keyed to case-hardened steel axles running in Hyatt roller bearings R.

The two wheel carriages are pivoted to the main steel frame by means of the anti-friction swivels S and S_1. They are thus able to traverse fairly sharp curves quite freely, without wheel-grinding and with but little noise. The suspension of the main rigid frame from the swivelling carriages is also an important feature. The load is directly carried by the interlocking steel stirrups of substantial construction. These are only centred by the swivel pins, which do not carry any loads. The operator's cabin is fully enclosed, and is provided with suitable doors and windows, as well as with a seat, the motor and brake controls being within easy reach.

This same telpher machine can be arranged to operate a two-rope grab for reclaiming coke from a stock heap and also for handling coal.

The Track.—Although there is much in common between a telpher and an electric runway, and both utilize a steel joist for the track, yet the telpher is of more substantial construction than the runway and is built in bigger capacities, both in respect of tonnage and in range and speed of travel. Also the heaviest type of telpher runs on the *top* of a joist-track fitted with a renewable steel rail rather than from the lower flange of a joist track, which gradually suffers wear.

A British standard joist measuring 18 × 7 in. and weighing 75 lb. per ft. has a bending modulus of 128 in.^{3} and a moment of inertia about the neutral axis of 1150 in.^{4} Such a joist will safely carry a travelling load of 8 tons over track spans of 30 ft. A bridge rail weighing 56 lb. per yard is suitable for the heaviest telphers and makes a better job than a bulb-headed rail of about 35 lb. per yard. For *curved* tracks, however, the latter is more convenient and is much used. It is not only cheaper but it avoids the need for countersunk-headed bolts, as it can be readily *clipped* to the joist flange.

For outdoor work a telpher machine is always provided with a closed *cabin* for the accommodation of the driver and his controls. For indoor work an open *cage* suffices. Current is supplied through bare conductors supported on insulators.

A Telpher-crane Combination.—A great extension to the sphere of usefulness of an electric runway or a telpher is obtained by coupling up its joist track at various places to a similar joist on a travelling girder or bridge running down a workshop bay on its own gantry. This combination forms a telpher crane or a form of transporter.

In one of the foundries of Ley's Malleable Castings Co. Ltd. erected in 1926 at Derby, the telpher cranes that can traverse the full length of the foundry loaded with a number of iron skips filled with light castings transfer their loads, at one end of the foundry, to a long telpher track erected in the open yard, which connects the foundry to the cleaning and inspection departments.

Telpher Track Supports.—When it is convenient to place trestles 20 to 30 ft. apart they consist, as a rule, of steel joists for the legs and angles or channels for the bracings. For a trestle 35 ft. high the sections for the legs may be 10 × 5 in. × 30 lb. per ft.

In the case of tracks 50 ft. high or more, it becomes economical to decrease the number of trestles and to introduce *girders* to carry the long track spans. The deadweight of these girders increases the vertical loads on the trestles. Moreover, the horizontal wind loads become important and have to be taken into account.

The detail design of trestles is fully dealt with in Herbert Blyth's " Modern Telpherage," where reference is made to the case of a track span of 80 ft. supported by a lattice girder, 6½ ft. deep, having an effective surface of 225 sq. ft. exposed to the wind. The *vertical loads* would then be about as follows :—

Weight of telpher machine	4 tons
Net working load	3 ,,
Weight of 80 ft. of track and rail	2 ,,
Weight of supporting girder	6 ,,
Weight of trestle, assumed	5 ,,
Total . . .	20 tons

Thus the dead load is 10 tons on each leg.

As regards the horizontal moments due to a *wind pressure* of 30 lb. per sq. ft., we have

	Load	Height	Moment
	Tons	Ft.	Ton-ft.
Girder . . .	3	66	198
Track . . .	1·5	59	88
Machine . . .	1	60	60
Trestle . . .	1	30	30
			376

If the trestle base is 20 ft., we have

$$P \times 20 = 376, \text{ or } P = 18{\cdot}8 \text{ tons.}$$

This is the upward pull on the foundation bolts due to the wind.

Thus the load on the *leeward* leg of the trestle is 18·8 tons due to the wind plus the dead load of 10 tons or a total of 28·8 tons. Also the load on the trestle's *windward* leg is 18·8 tons upward plus 10 tons downward, or a total upward pull of 8·8 tons.

Taking the maximum slenderness ratio K as 160 for a strut with fixed ends and the *effective* length of the strut as $1\frac{1}{3}$ times the actual length, *i.e.*, considering one end fixed and the other rounded, the radius of gyration R in inches becomes one-tenth of the unsupported length of the strut expressed in feet. Hence, in this case

$$R = 63 \div 10 = 6{\cdot}3 \text{ in.}$$

Assuming a maximum stress of 2 tons per sq. in., the sectional area of each trestle leg will be the total load divided by the allowable stress or 28·8 ÷ 2 = 14·4 sq. in. Adopting two channels braced together, each channel should have a section of 7·2 sq. in. If these channels are placed 16 in. apart the necessary radius of gyration of the section will be obtained.

Many tall telpher tracks have been supported on square braced towers or columns built up from steel angles and flats.

The Cost of a Telpher naturally varies a good deal from time to time, according to the prices of materials and the rates of wages prevailing. Yet one can gain an approximate idea of the cost of this class of plant from a study of the particulars of a typical telpher detailed by Herbert Blyth in his book on " Modern Telpherage."

An installation for handling coal and ashes was erected at the electricity works of the St Pancras Borough Council, London, during the years 1916, 1918 and 1919, in three separate contracts, the total value being £7560. This includes a 40-ton ash hopper.

The total weight of the telpher *structure* is 80 tons and its value £3600, or £45 per ton of steelwork. This comprises in the first place 600 ft. of track (14 × 6 in. × 46 lb. per ft.) with bulb-headed rails weighing 30 lb. per yard, amounting to 16 tons, besides 6 tons of track hangers. The largest item, however, is 25 tons of lattice steel girders, and the next is 20 tons of trestles, which are 71 ft. high. Lastly, there are two rectangular towers weighing 13 tons. The value of the *machinery* alone is £1800, and it is worth fully £120 a ton.

The telpher machine or crab used at St Pancras is rated for a gross load of 3 tons. It lifts at 80 ft. per min. and travels at 600 ft. per min. It is fitted with a single-chain grab of 30 cwt. capacity which makes up to 30 working cycles per hour, giving a capacity of 45 tons of coal per hour.

Both the 24-H.P. hoist motor and the 8-H.P. travel motor are operated by a single controller with a change-over switch, the usual practice being to hoist up the load to a position that will safely clear all obstructions before starting the travel motor.

Such a machine has an economic life of about fifteen years. The total maintenance cost works out to about two-thirds of a penny per ton of material handled.

A Radial Transporter.—Plate 36 (A) depicts an interesting radial transporter for coal of 153 ft. radius and 2 tons capacity, which covers a large area of storage ground. It was erected by Babcock & Wilcox Ltd. in Ayrshire for Imperial Chemical Industries Ltd. In this design one end of a light lattice braced bridge is pivoted over a receiving hopper while the other end describes a semicircle. Here it is not necessary to move the bridge as part of the regular cycle of operations. This is done only when the bridge has to be set to suit the coal waiting to be handled. Normally only the electric crab or telpher machine, along with its multiple-rope grab carrying the coal, are moved to and fro in transporting the coal into and out of storage.

A Rectangular Layout.—Contrasting with this semicircular layout is the rectangular storage plant depicted in Plate 36 (B) which was erected at Bowater's Mersey Paper Mills, Cheshire. This transporter crane is designed to work in conjunction with a system of coal conveyors to handle 100 tons of coal per hour into or out of storage. Here a Warren girder bridge of 120 ft. span, travelling on elevated fixed gantry rails, carries a 4½-ton electric jib crane of 25 ft. radius, equipped with a multiple-rope grab feeding coal into a travelling receiving hopper. This crane reclaims coal from the open storage ground and delivers it *via* the hopper to a 22-in. belt conveyor carried by the bridge.

Another interesting example of a travelling transporter bridge is illustrated on Plate 42 (A). This machine is equipped with an electric man-trolley, controlling the operations of transferring coal to and from capacious railway trucks by means of a grab. It was made by the Industrial Brownhoist Corporation of Bay City, Michigan, U.S.A.

CHAPTER XXII

ROPE-TROLLEY TRANSPORTERS

In the foregoing chapter some examples have been given of that type of transporter where the load is carried by a self-propelled car or crab, equipped with both hoisting and travelling gears operated by electric motors and controlled by a man travelling along with it.

Although this type of machine has developed greatly during the last thirty years, following the introduction of telphers, it has its drawbacks as well as its merits. The chief merit of the telpher type with its ‘ man-trolley ’ is superior visibility, for the operator in his movable control cabin can easily see what is happening directly below him and can act accordingly. Its chief drawbacks are its relatively high first cost and its slowness, as compared with its high-speed rope-trolley rival, when engaged on regular repetition service such as grabbing coal or unloading bags of sugar from barges into store.

The Self-landing and Delivery Hoist.—This is perhaps the simplest type of machine that sometimes goes under the name of transporter. One design is illustrated in Fig. 145. It lifts a load, transports it horizontally a short distance and then lowers it, all by different movements of one lever handle. This friction hoist is much used for loading and unloading lorries and barges with bales, bags and similar goods. An example of its application is depicted on Plate 38.

The traveller beam usually projects outside the warehouse by some 10 ft. over a yard, street or canal. The beam can be made to rack in and out, or to hinge upwards when a permanent projection outside the building is prohibited. In some cases the track extends for a considerable distance beyond the wall and is supported by a trestle or two.

This simple form of transporter finds extensive application in cotton mills, warehouses, paper mills and printing works.

Loads of from 5 cwt. to 3 tons can be lifted by a chain or a rope at speeds ranging 50 to 200 ft. per min., and traversed at speeds up to 400 ft. per min. Control for all motions is by a single handle connected to the friction mechanism by a chain or a rope. This handle is placed in the most convenient position for the operator to see the movements of the load hanging on the hook.

The load trolley is arranged to stop automatically at each end of the beam, quite independently of the operator, thus preventing accident and undue wear. The trolley can also be stopped at any point of its travel desired.

The main friction wheel on the hoisting winch is bolted to the rope drum and runs loose on the drum shaft, which is mounted eccentrically in the side frames. The drum shaft is rotated by means of a lever when the frictional hoisting gear is to be engaged.

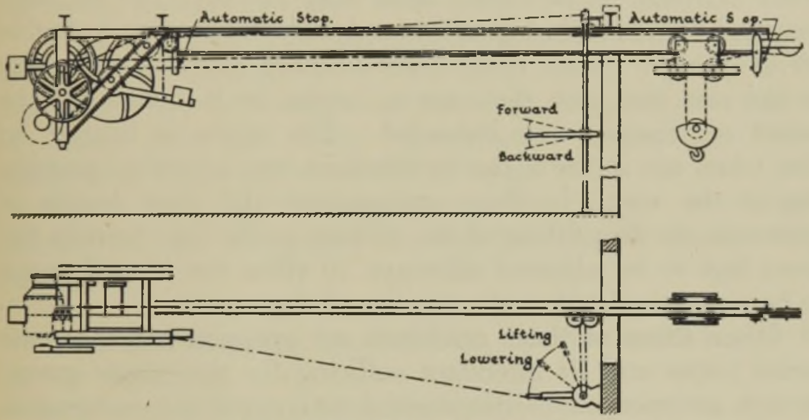

FIG. 145.—Self-landing Hoist.

In order to lift the load in the best type of self-landing hoist one raises the control handle to the highest point, and to put on the brake, one drops the handle. To move the trolley outwards, one pushes the handle outwards, and *vice versa*. By means of a friction wheel the trolley can be traversed in either direction. The drive is either by a belt pulley or by a motor. The trolley track is conveniently supported by floor joists or by the roof principals.

Early in this century Joseph Horner emphasized the recent rapid development of certain types of light cranes of exceptionally long range and of remarkable mobility, namely, the Brown and the Temperley transporters, both of these being long-armed high-speed cranes, which were at that time better known in the United States than in England.

Brown Bridge Transporters.—In the so-called ‘ bridge tramways ’ of the Brown[1] Hoisting Machinery Co., as depicted on Plate 37, the material being handled (often coal or ore) is hoisted and carried by a rope trolley a distance of 300 ft. or more, then dumped and the trolley run back all within a minute. Consequently the cost of handling becomes very low.

The total length of the bridge may be divided into two or three sections. The centre span may be, say, 180 ft., supported by one single leg and one double leg having a double set of wheels. Then there is a cantilever, perhaps 90 ft. long at the rear, and also the ‘ apron ’ some 30 ft. long over the vessel or trucks being unloaded. The apron is hinged, so that when not in use it can be lifted up into a vertical position out of the way. In these transporters the great length of span and the free fitting of the girders to the legs permits the front legs to be adjusted sideways, to allow the hinged apron to be accommodated to the hatches of the vessels.

Often three of these machines are grouped together, one steam boiler and its attendant sufficing for the whole group, though an operator is also needed to control the movements of each bridge. The steam engines run constantly in one direction, reversal of the motions being effected by friction clutches and gearing. The working capacity of each transporter exceeds 40 tons of coal or ore per hour, and the load is often weighed automatically when in transit.

The Temperley Transporter.—In its earliest form this type of transporter dates from the year 1892, when Joseph Temperley took out his original patent, the beam on which the trolley or ‘ traveller ’ ran being *inclined* fully 1 in 8 and only some 50 ft. long.

In later designs both the length and the speed of working were greatly increased. A special feature of the machine is an ingenious device, including an automatic catch, by means

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[1] Since I visited their works in Cleveland, Ohio, in the year 1923, the name of this well-known American firm has been changed to the Industrial Brownhoist Corporation and the location to Bay City, Michigan.

of which the trolley is kept stationary on the beam while the load is being lifted, and also the load is held suspended at one level while the trolley is moving along the beam.

A Temperley transporter comprises three main parts, namely (1) a steel beam of I section, (2) an automatic trolley and (3) a fixed winch, either steam or electric or hydraulic, which operates the trolley by means of a single wire rope. The load can be discharged at any number of fixed points on the beam, under control of the operator.

For handling lumpy coal the transporter can be fitted with a two-rope grab, giving the power and convenience of lifting and lowering at the same time as the trolley is moving along the beam, neither operation interfering with the other.

Some examples of actual early installations are given later, but it would be tedious to describe in detail the automatic mechanism for travelling and dumping the load, in regard to which reference might be made to Zimmer's "The Mechanical Handling of Materials," page 493.

Merits of the Transporter.—The many advantages claimed for the Temperley transporter may be enumerated thus :—

1. It is economical in first cost, in maintenance and in working.
2. It is simple in construction and in manipulation.
3. It can be made with a big outreach from the point of support, and can therefore combine the duties of a crane and of a conveyor.
4. The load can be lifted, transported, lowered and dumped by the operation of one rope, in most cases.
5. The weight of the load when in transit is not on the rope but on the trolley.
6. The moving mass is a minimum and its inertia is therefore small.
7. The load can be lowered at fixed points anywhere in the line of transit at pleasure.
8. The load is handled in the quickest possible manner, because the transportation is in a straight line.
9. Skips and grabs can be dumped automatically at any desired *height*, thus minimizing the breakage of material.

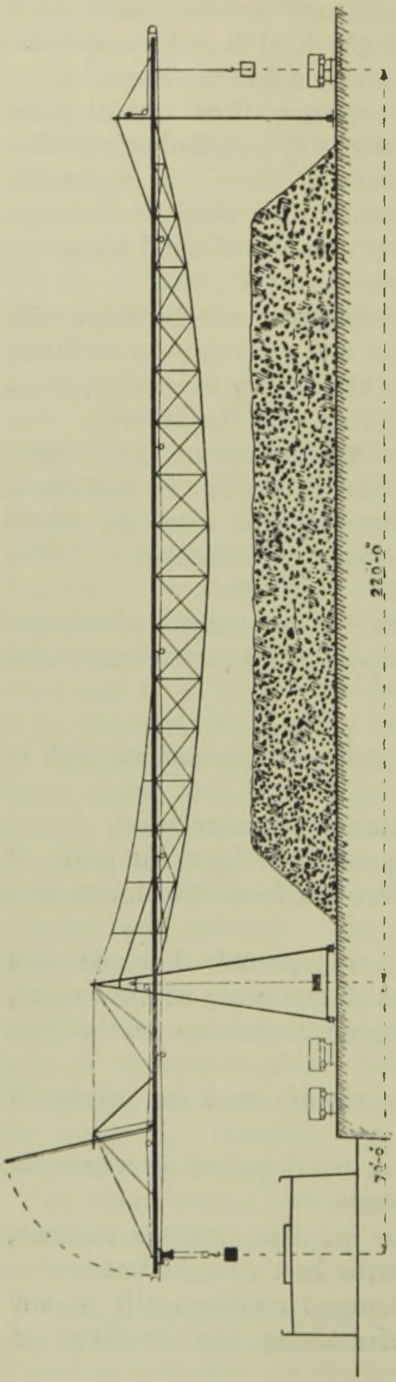

Fig. 146.—Travelling Bridge Transporter for Coal.

The Temperley Bridge Transporter outlined in Fig. 146 is designed for unloading coal from vessels into an open coal store, the total reach being 290 ft. The transporter beam is carried by a light bridge over the stock heap, being supported at one end by a steel tower mounted on wheels running on a double-rail track, and at the other end by a steel A frame or trestle mounted on wheels running on a single rail. The connections are so designed that the trolley beam can be slewed to an angle of about 12° on each side of the centre line.

The motor-driven winch fixed on the tower is capable of lifting a *skip* of 50 cub. ft. capacity, containing 25 cwt. of coal, at a speed of 250 ft. per min., and transporting the same along the beam at the high speed of 800 ft. per minute.

For travelling the bridge along the rails one motor is mounted on the tower and another motor on the A frame. On the tower is also situated the driver's cabin, from which all operations are controlled.

A portion of the I beam is equipped with an automatic weighing and recording machine, which weighs each load of coal as it passes over this section in automatic dumping skips.

A group of three Temperley transporters was erected by Sir William Arrol & Co. Ltd. to serve a coal store at *Portsmouth*, one of them being depicted on Plate 40 (A). Here the open coal store has ferro-concrete walls, on which are laid the tracks of the transporter girders spanning the store. The hinged cantilever beam extends over the hatchway of the vessel being either loaded or unloaded. The capacity of each machine is 75 tons of coal per hour taken from ship to the centre of the store, the grab holding 25 cwt. of coal. There is little breakage of the coal, and the plant is economical of power.

A Tall Grab Transporter is outlined in Fig. 147, which indicates a machine [1] installed by a South American railway company for transferring locomotive coal from ships to a storage ground at the rate of 80 tons per hour. The unusual tallness of the plant is due to the height of the bunkers to be filled. This transporter is electrically operated.

Here the rope trolley carries a *grab*, which is filled in the hold of the ship without labour and emptied into the hopper of a weighing machine that is arranged to travel along the top of the girder bridge. After weighing, the coal is dropped into the bunker. The weighing machine is carried by a telescopic frame that can be raised or lowered to suit the level of the coal in the bunker, and thus avoid a big drop causing breakage.

A special feature of this transporter is that either of the supporting legs can be moved laterally through a limited range quite independently of the other. Thus one end of the bridge might be fixed over a hatchway whilst the other end could move over a distance of 72 ft., so as to spread the coal well. Only two men are needed to operate the plant, one at the weighing machine and the other to look after the transporter.

The Bournemouth Gasworks Transporter.—One of the earliest and most noteworthy examples of a Temperley transporter of the travelling-bridge type for double-rope operation was installed at the Poole works of the Bournemouth Gas and Water Co., in order to discharge coal from colliers

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[1] See *Transactions of the Institution of Engineers and Shipbuilders in Scotland*, vol. lvii. (J. H. Hunley's remarks.)

and from railway trucks and to deliver it either to the storage ground or to a conveyor that takes the coal direct to bunkers

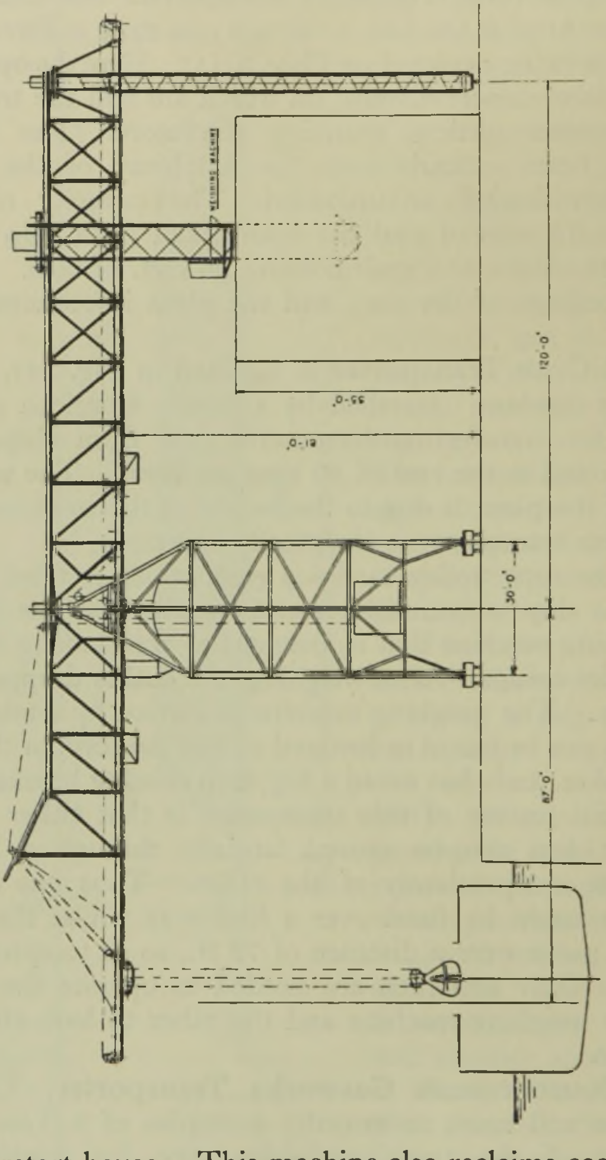


Fig. 147.—A Tall Rope-trolley Transporter for Coal.

in the retort house. This machine also reclaims coal from the open storage ground and delivers it to the same conveyor.

The general layout of the Bournemouth transporter does not differ greatly from the last example, but in this case the bridge has a clear span of 180 ft. between the track rails and

PLATE 43

Babcock & Wilcox Ltd.

A.—SKIP HOIST FOR ASHES.

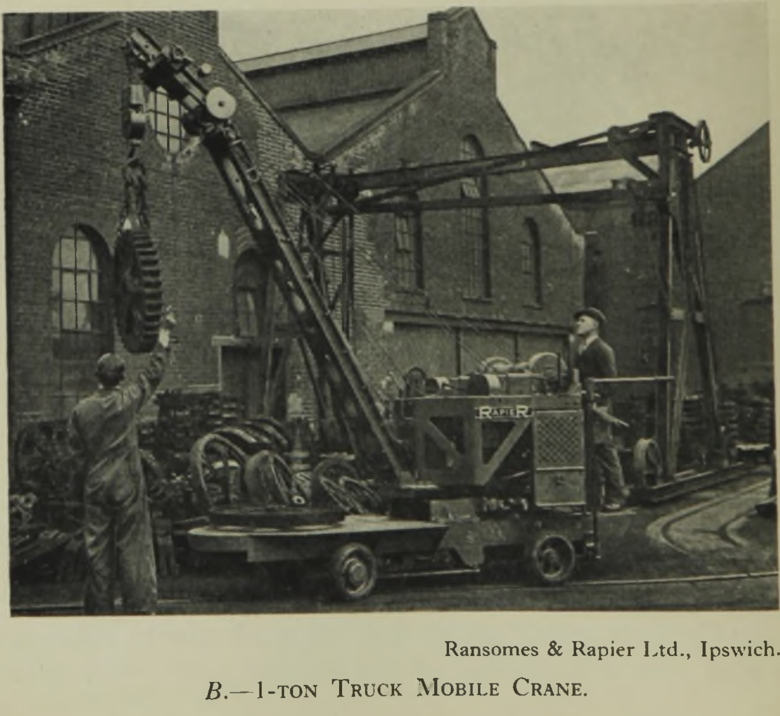
Babcock & Wilcox Ltd.

B.—ELECTRIC TRUCK HOIST.

[*To face page* 272.

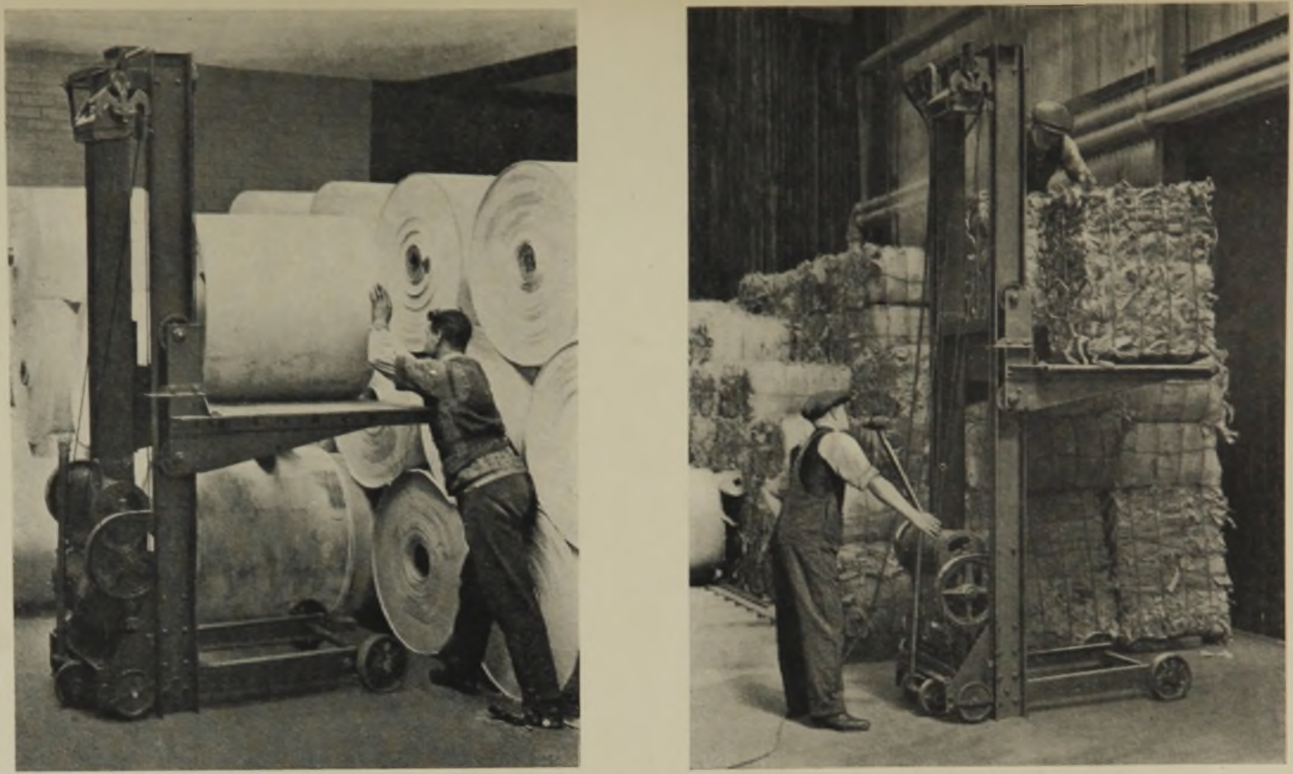
J. Collis & Sons Ltd., London.

A.—LIFTING TRUCK AND TRANSPORTER.



Ransomes & Rapier Ltd., Ipswich.

B.—1-TON TRUCK MOBILE CRANE.



Herbert Morris Ltd.

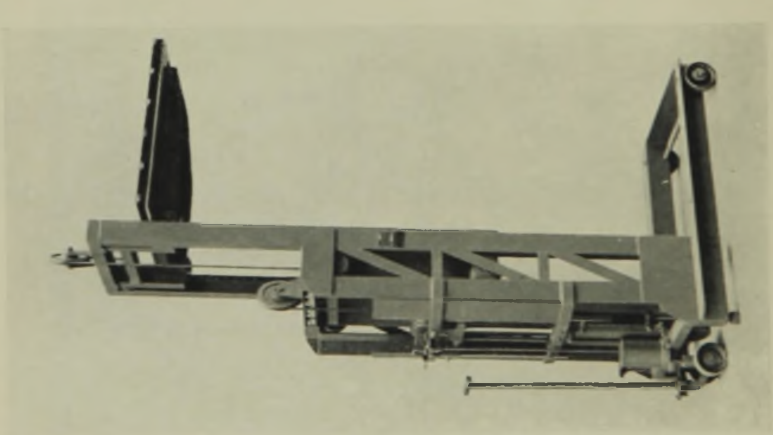
Herbert Morris Ltd.

ELECTRIC GEARED STACKERS FOR ROLLS AND BALES OF PAPER.

PLATE 46

J. Collis & Sons Ltd.

ELECTRO-HYDRAULIC STACKER.



J. Collis & Sons Ltd.

TELESCOPIC HAND STACKER.

To face page 273.]

a cantilever extension of 91 ft. over the quay, of which a 20-ft. length overhanging the water is made to hinge up, so as not to obstruct the waterway permanently.

The transporter beam proper forms the lower boom of a girder of triangular section ; a design that combines the greatest strength with the least weight. The bridge and the cantilever are built into two supporting legs at a clear height of 42¼ ft. above the rail level. The leg nearest to the quayside houses the whole of the hoisting and transporting machinery. It also carries a cabin in an elevated position, from which the driver who controls all the operations has a good view of the grab.

The other leg, near the retort house, carries a coal breaker, also a hopper and a chute to the conveyor. Moreover, a movable framework is slung from the bridge and on this is arranged a hopper weighing machine.

The coal-handling machinery is motor-driven, the electric current being collected from live rails in a conduit running parallel to the conveyor. The grab is operated by a *double-drum* winch, which has the drums connected by an epicyclic gear so arranged that either both drums can be run together to lift and lower the grab bodily or one drum may be held by a brake whilst the other drum revolves and operates the opening and closing rope. The grab can be lifted bodily either open or closed, and its jaws can be fully opened at any height.

A separate *single-drum* winch is provided for the purpose of hauling the trolley along the beam in either direction, by means of two ropes wound in opposite directions. When the trolley is being pulled along the beam the compensating epicyclic gear in the *hoisting* winch causes its two drums to revolve in reverse directions, thus hauling in one hoisting rope and paying out the other, so as to keep the load at one height as it moves along the beam. The load can be raised or lowered at any desired *speed* just as readily when the trolley is moving as when it is at rest.

Before this transporter was installed at the Poole gasworks as many as seventy men were employed in handling coal there, whereas only eleven men were afterwards needed, namely, the driver, the weighman, eight trimmers and one foreman on the collier.

TOWER TRANSPORTERS

Although the Temperley transporter, already described, has been applied quite successfully in the travelling-*bridge* form, yet the travelling-*tower* type has been utilized on a still more extensive scale, as will be seen from the study of a few typical applications.

The structure or tower is of the portal type, allowing wagons to pass underneath the platform, on which are mounted the steam boiler and the steam winch for operating the transporter. The beam track is considerably inclined. This is a usual feature in tower transporters, though actually the track can be made either inclined or horizontal. When inclined sufficiently, however, the weight of the special trolley itself causes it to run down the slope automatically, whereas when the track is made horizontal an overhauling rope has to be attached to the trolley and connected to balance weights for the purpose of bringing the trolley back. Yet in either case the operations of lifting, transporting, lowering and dumping the load from a suitable skip are effected by the simple action of hauling in and paying out a single rope.

While the load is actually being lifted the special trolley or ‘ traveller ’ remains automatically locked to the beam. When the load reaches the full height, however, the trolley takes the weight and becomes released from the beam. It then runs along until it reaches a point where the operator wishes to discharge the load. He then pays out the rope under control of the brake, when the trolley at once again locks itself to the beam and the load can be lowered to the desired level.

When an automatic dumping skip is being lowered, immediately on starting to haul in the lifting rope, the mechanism of the special ‘ fall-block ’ trips the latch of the skip, which then dumps its load and returns empty to the starting point without any loss of time. Hence this transporter is extremely rapid in operation.

A Glasgow Power-house Application.—Fig. 148 indicates a transporter erected at the Glasgow Corporation Electricity Works, Port Dundas, to unload coal from canal barges and deliver it into the storage hopper in the boiler-house. In this early example coal is lifted from the barge in skips holding 15 cwt. and provided with drop-bottom doors, out of which the coal falls into a hopper on a movable weighing machine, whence it is discharged into storage bins.

This is only a small plant, the total reach being 97 ft., made up of 45 ft. on the canal side, 40 ft. on the land side and 12 ft. width of the tower. The load is only 22 cwt. gross. The tower is here mounted on an under-carriage of unusual gauge (19 ft.), due to the special requirements of the site.

As the water-side arm extends over a road, it is hinged up by a derrick barrel on the motor-driven winch into a vertical position when not actually in use.

So successful was this early transporter that at a later date a second one was installed on an adjacent site, but with certain improvements. This second machine is more powerful than the first and it works on the two-rope system. A grab is used instead of skips, the gross load being 45 cwt. The trolley has a total transporting range of 100 ft., made up of an over-reach of 46 ft. on the water side, 34 ft. on the land side and 20 ft. over the tower, the rail gauge being 19 ft. 4 in. The lifting speed is 240 ft. per min. and the trolley speed 600 ft. per min.

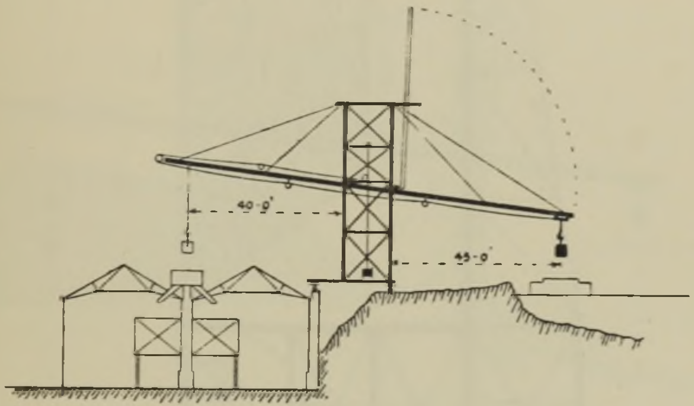


Fig. 148.—Cross-section of Site at Glasgow.

The line diagram (Fig. 149) gives a general idea of a 3-ton non-slewing travelling-tower transporter with a *horizontal* beam, designed for grabbing coal from barges or colliers and delivering it at pleasure either to a stock heap or into railway trucks running beneath the portal tower.

Such a machine with *grab* has naturally to be made much

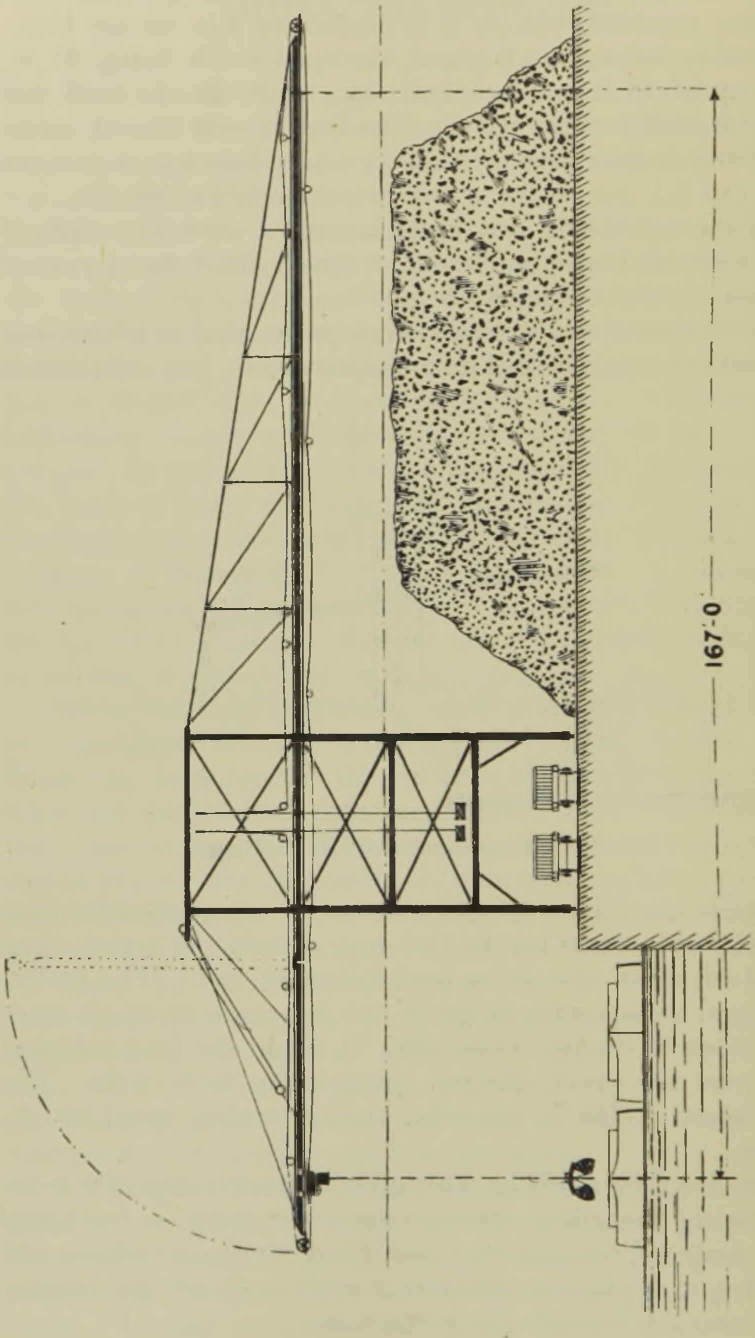


FIG. 149.—Horizontal Tower Transporter for Coal.

heavier than one handling coal in *skips*, and consequently its first cost is relatively high. But where the circumstances are favourable the saving in the cost of filling skips by hand labour in the barge gives full justification for the extra capital expenditure.

In this case the automatic grab has a capacity of 57 cub. ft. and holds about 25 cwt. of coal. The overreach is 100 ft. on the land side and the gauge of the rails on which the machine travels is 26 ft. As usual the water end of the trolley track is arranged to hinge up.

A Coal Transporter at a Spanish Ironworks.—Fig. 150 outlines a steam-driven tower transporter erected at Bilbao for discharging coal from vessels, for conversion into blast-furnace coke. There is a clear overreach on the land side of 100 ft. and of 56 ft. on the water side. As the gauge of the rails is 26 ft., we get a total effective length of the transporter beam of 182 ft. The shorter end of the beam is made to hinge up, out of the way of the masts of ships coming alongside the wharf.

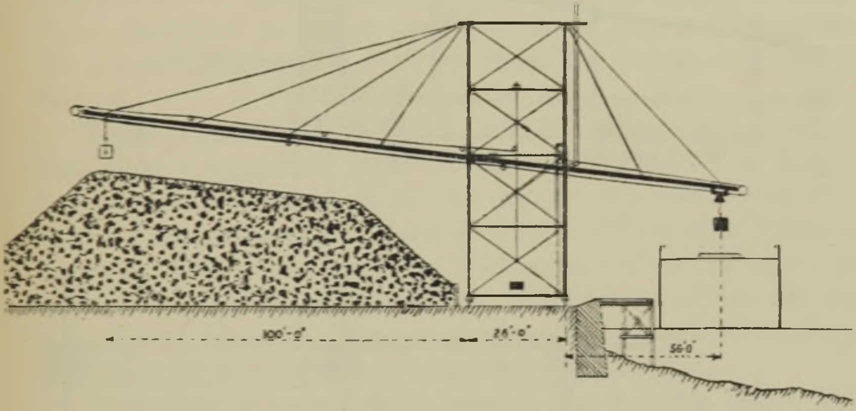


Fig. 150.—Coal Transporter at Bilbao.

When using automatic dumping skips of 25 cwt. capacity the rate of working is fully 60 tons of coal per hour. A gross load of 35 cwt. is lifted at a speed of 250 ft. per min. and transported along the beam at fully 600 ft. per min. All the motions are actuated by a steam engine, including moving the entire transporter along the track, so as to be able to take coal from different hatchways and deposit it at different parts of the stock heap for stacking.

A Combination System of Transporters.—At the Portuguese port of Delagoa Bay in East Africa there has been erected an interesting installation of transporters for unloading ocean-going ships and transferring their cargoes into transit sheds and railway trucks. As shown in the line drawing (Fig. 151) there are four travelling tower portal transporters, running along the quayside or wharf, working in conjunction with no less than thirty-six inclined transporter beams fixed inside the extensive transit sheds, arranged in three groups. These fixed beams are spaced 5 metres apart and extend over the railway trucks at the back of the sheds. The coupling up of the travelling machine to any one of the fixed beams is effected by the driver from his position in the machinery house.

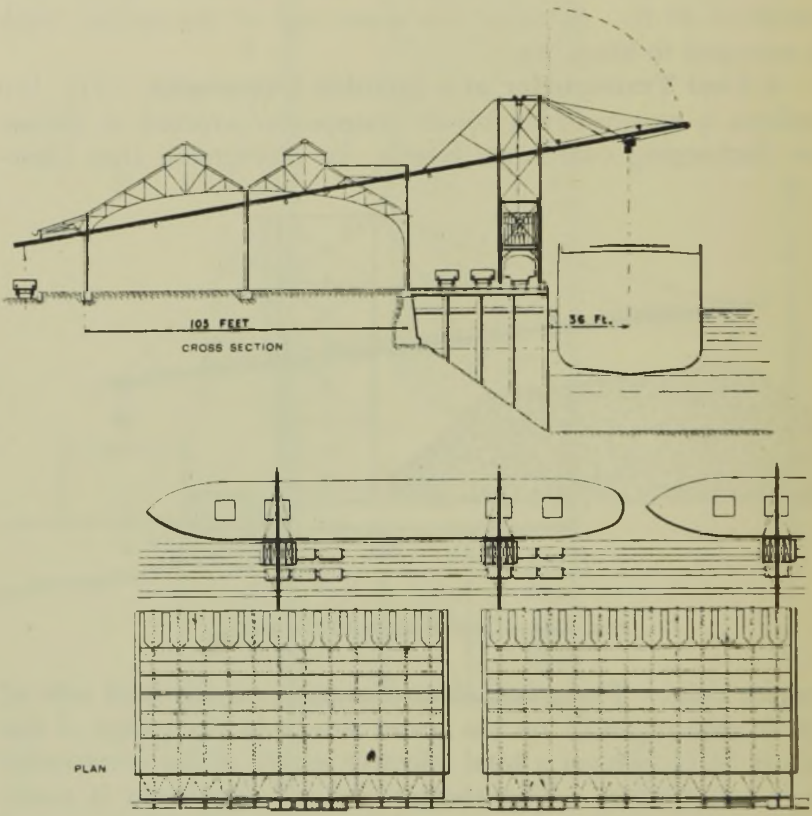


FIG. 151.—Cargo Transporters at Delagoa Bay.

Cargo is hoisted from the ship in slings and lowered either into trucks on the wharf or into any required position in the sheds, or even placed directly into trucks standing on rails at the back of the sheds. The motions are operated by electric motors, the speeds with full loads being 75 and 250 metres per min. respectively for hoisting and transporting.

Although this extensive plant was primarily designed for unloading cargo from ships and putting it into store, it can also be used in the opposite sense for taking goods from railway trucks into store or for loading vessels with cargo taken from the transit sheds.

Sufficient attention having been given to Temperley transporters it now remains to consider briefly some other types described as either transporters or transporter-cranes, the line of demarcation between these not being very clearly defined.

Transporters for Sugar.—Plate 39 (A) depicts a group of high-level transporter cranes, made by Ransomes & Rapier Ltd., erected in position on the top of the raw sugar silos at the Lyle refinery of Tate & Lyle Ltd. on the Thames. A closer view is also given at B of a later crane of this type erected at the Thames Refinery, Silvertown, where the big plated wind balancing vane at the machinery end of the long cantilever jib is a noteworthy feature.

This vane is intended to balance the turning effort of a high wind on the projecting jib by providing a larger wind area at a smaller radius, thus equalizing the turning moments and preventing undesired rotation in a gale. The jib of the middle crane only is *hinged*, as the two outer cranes can be slewed round to clear the quay line when required.

The duty of these roof cranes is to raise and transport bags of sugar, fifteen at a time, from river barges into the stores. They are of the four-motor type, having separate hoisting, slewing, traversing and travelling motions. The cable connections to the motors are visible in the close-up picture.

The maximum capacity of each crane is 2¼ tons on the hook, at a radius of 90½ ft. The weight of one crane in working order is 102 tons, including the counter-balance filling of 22½ tons. The roomy machinery house is seen over the travelling tower or gantry, while an amply lighted driver's cabin is placed well forward in a favourable position for observation.

In these transporters the *reeving of the ropes* is quite simple, as indicated in Fig. 152. The load is lifted on two parts of rope, each end being anchored to the hoisting drum, which has both right and left hand spiral grooving. The ends of the traverse rope are secured to the load trolley, this rope passing over guide sheaves and winding round the traverse barrel on a continuous spiral groove. As the tight side of the rope winds on one end of this barrel the loose side unwinds from the other end. Since the lifting and traversing motions go on simultaneously the hook moves diagonally, carrying its load of fifteen bags of raw sugar. Thus the action is very rapid.

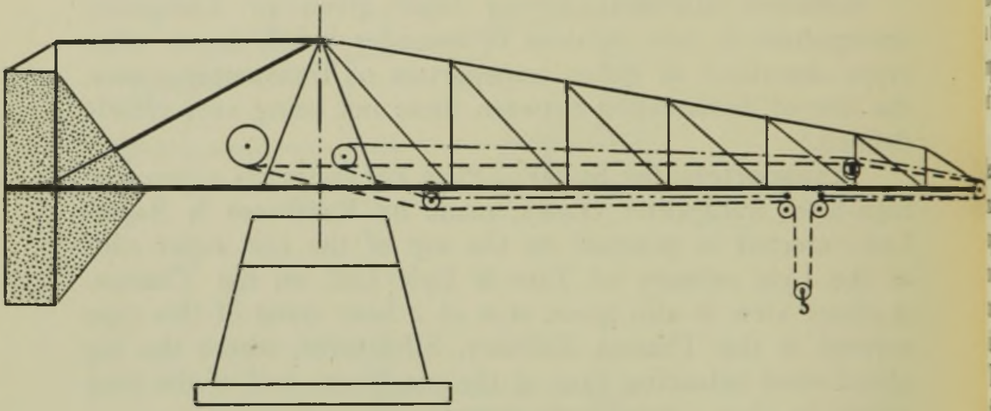


Fig. 152.—Reeving of Transporter Ropes.

In the background further along the wharf are seen a pair of Temperley transporters which have been used for many years in loading finished sugar into barges and small vessels, picking up a dozen 2-cwt. bags at a time in rope slings. Only one of these machines has a slewing motion.

A Double Coaling Transporter.—Plate 40 (B) depicts a three-motor fixed transporter crane for coaling ships, made by Ransomes & Rapier Ltd. for the London and North Eastern Railway Co., Hull. Using two 1-ton buckets or skips, this crane has a capacity of 100 tons of coal per hour, its weight in working order being 78½ tons. The cantilever jib has two single-joist tracks, one for each trolley, so that this machine might be styled a duplex transporter.

On this machine the buckets or skips have bottom opening doors operated by a hold-rope barrel in much the same manner as if it were a hold-rope type of grab. Another feature is that each of the main hoisting drums has anchored to it a counterbalance rope leading to a balance weight in the rear leg of the structure. Hence the rope-reeving of the entire duplex transporter becomes quite complex. It can best be followed on a drawing by utilizing four contrasting colours for distinguishing the various ropes.

The ropes are made of the best quality extra-flexible steel wire, having six strands of thirty-seven wires each, and are not galvanized. They are all of $1\frac{1}{2}$ in. circumference with a breaking strength of 7·9 tons, except the heavy derricking rope, which is $2\frac{1}{2}$ in. circumference, having a breaking strength of 22 tons.

Tracing first of all the *derrick rope*, one end of this on leaving the derrick-barrel passes over a top sheave on the mast frame, then down to a sheave on the jib, back to a second top sheave, and down to a horizontal jib sheave ; then across to its mate on the other side, up to a third top sheave, down to another jib sheave, up to a fourth top sheave, and finally down to its anchorage on the other end of the derrick barrel. Thus the rope winds on the barrel in two parts but it raises the jib in six parts. The motions other than the derrick motion are duplicated.

For *traversing* the two trolleys four lengths of rope are used, one end of each rope being anchored to the traverse barrel and the other end to the trolley itself. There are guide sheaves at each end of the twin-channel track and supporting sheaves at two intermediate points on the upper run only. As the pulling rope winds on to the barrel, so does the slack rope unwind to the same extent.

Each of the two *lifting ropes* is anchored at one end to the hoist-drum, situated near the derrick barrel at the rear of the jib. The rope passes horizontally along the jib, where it is supported by two sheaves and around an end sheave. The lifting rope then passes over a trolley sheave, down to a bottom sheave, then up to another trolley sheave and on to its anchorage at the rear of the jib.

One end of each of the two *counterbalance ropes* is secured to its anchorage on the rear framework by means of a thimble embracing a pin $1\frac{1}{2}$ in. diameter. From this fixed point the rope passes vertically downwards and around a bottom sheave, upwards and around another sheave, then down again and around another bottom sheave, upwards to a corner guide sheave and finally on to the main hoist drum.

The rope for operating each coal bucket or skip is secured at one end to an opening barrel, geared to run at the same speed and in the same direction as the hoist drum. This rope passes horizontally along the jib, with two supports, around a jib-end sheave, on to a trolley sheave, down to a bottom sheave, up again to a second trolley sheave and then along the jib to a fixed anchorage. This completes the rope system.

A Multi-purpose Foundry Transporter.—Plate 18 (B) illustrates a tall $2\frac{1}{2}$-ton electric travelling transporter crane, made by Babcock & Wilcox Ltd., for serving the iron foundry of the Austin Motor Co. Ltd., Birmingham. Its maximum radius is only 32 ft. and its moment 80 ton-ft. This machine handles moulding sand by means of the self-dumping grab shown suspended, which, however, can also be operated at will by the driver.

Alternatively the crane can lift both pig-iron and scrap from the foundry yard or from railway trucks by means of an electromagnet of 36 in. diameter and transfer its load to the hopper shown at the roof level. Thus the machine is one of general utility.

BALANCED CANTILEVER CRANES

Closely allied to the Temperley tower transporters are the Brown balanced cantilever cranes, as used in some shipbuilding yards. The cantilevers being of equal length and projecting well beyond the central pier or tower, one crane will cover two adjacent berths between which it travels on an elevated fixed gantry running the full length of the launching ways. Though somewhat similar in general design to the transporters, these special cranes are of more substantial construction and of bigger lifting capacity, ranging from 5 to 15 tons as against $1\frac{1}{2}$ to 3 tons.

As Joseph Horner once remarked, it seems singular that so long a period elapsed before the double-arm crane was invented. The germ of the idea is in the balance crane. But instead of tons of useless ballast, the Brown crane provides two useful balanced working arms of equal length, one on each side of the carriage. The cantilevers may be either rigidly fixed to their piers or the superstructure may be made to revolve. The construction permits of lifting at any radius without the complication and risk of slewing maximum loads that exist on the ordinary balance crane. A long-radius double-armed crane may revolve through a circle as much as 300 ft. across.

The great width of the wheel-base affords ample stability. Any unsteadiness due to the varying radius of the trolley and its suspended load is provided against by a counterbalance weight running along a special track on the bridge. This weight is so connected by ropes to the trolley that it automatically takes up a position on one arm at the same radius as the load on the other arm. It is remarkable to observe how very steadily the entire crane travels at a high speed.

In the case of a double-armed crane erected at a Barrow shipyard, the trolley traverse is no less than 318 ft., which covers a large plate store yard. The moment of this crane is 5 tons × 159 ft. or 795 ton-ft. A motor of 85 H.P. lifts the load at the rate of 200 ft. a min., traverses the trolley at any speed up to 750 ft. a min., and travels the whole crane along its gantry at about 300 ft. a min. Two other cantilever cranes, serving the building berths at the same shipyard, are each of 15-ton capacity.

When crane girders are built of solid plates the wind resistance is considerable, and in exposed storm-swept areas there may be some danger of a crane being blown over. The enormous cantilevers of the Brown cranes, however, are built and braced so lightly that such danger vanishes. This is feasible because only a light trolley runs along the track, not a heavy crab carrying machinery.

The old system which arose with the steam-driven travelling cranes, of mounting the motive power and gears on the crab, was a bar to better and more economical design. A crab so loaded is very heavy and produces three evils. Excessive power is needed to operate it; there is difficulty of stopping quickly when momentum has been acquired, and also needless weight has to be borne by the structure in addition to the load proper.

In the newer double cantilever cranes these evils have been completely avoided. The crab motions are supplied by wire ropes, driven by motors situated in the base of the pier or tower, just where weight is wanted. Thus the bridge girders have little to carry save their own deadweight and the load lifted. Hence, though of great length, they are spider-like structures offering a minimum of surface to wind pressure and yet carrying the load safely and efficiently.

CHAPTER XXIII

SKIP HOISTS AND TRUCK HOISTS

A Simple Skip Hoist that has been applied successfully for handling ashes and clinker is shown in Fig. 153. This is a preferable alternative design to the continuous-bucket type of chain elevator, the upkeep of which is apt to become expensive on such severe duties. Here, instead of a series of small buckets bolted to a chain running continuously, there is one large bucket or skip working intermittently, having a capacity of some 10 cub. ft. or more. Either hot or cold ashes

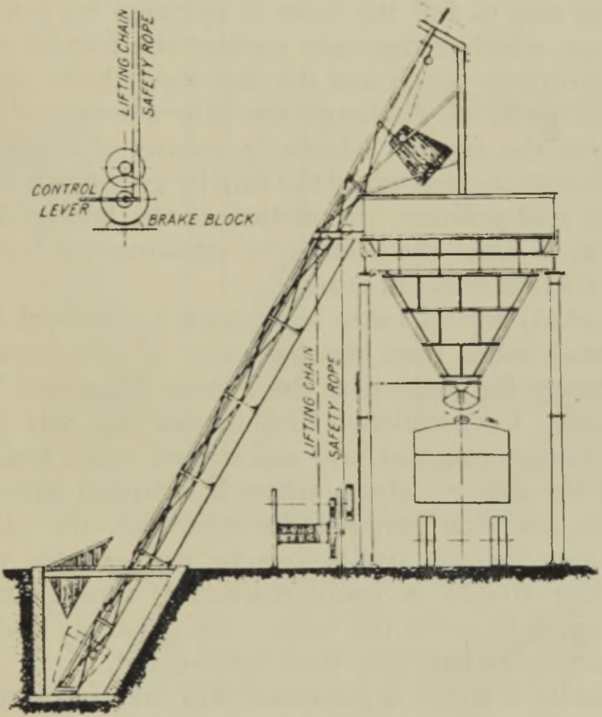


Fig. 153.—Skip Hoist for Ashes.

and lumps of clinker can be conveniently raised in this way, while the lifting chain is not exposed to the destructive action of the ashes.

The skip has four small flanged wheels or rollers, running on two tracks which diverge at the top, so that when the skip is in its highest position it is automatically tipped and its contents discharged into a bin or storage bunker fitted with hinged emptying doors. The bin is erected high enough to permit either motor trucks or railway wagons to pass beneath it for removing the ashes. On this service a riveted steel bin is less durable than one made of cast-iron plates.

When in its lowest position the skip is filled from a small hopper chute, receiving ashes from iron barrows or trolleys. When the skip is full the hoist is operated by pulling up a hand lever, which brings into contact the friction wheels of the power-driven winch and the skip then climbs upwards.

At the point of discharge the skip automatically throws out of gear the friction wheels by means of a light control rope. During the descent of the skip by gravity the hand lever is held in mid-position, the motion of the falling skip being checked as it nears the bottom by releasing the lever, which puts the friction brake in gear.

Plate 43 (A) depicts a skip hoist, made by Babcock & Wilcox Ltd., raising ashes from the basement of a boiler-house up into a storage bin erected at the Provan Chemical Works of the Glasgow Corporation. In this case the ash trolley or wagon is run on to a platform and is then raised bodily to the height of the delivery chute, where it is tipped automatically. The attendant then reverses the controller, the platform is lowered and the ash trolley can be run out for reloading. Part of the weight is counterbalanced, thus reducing the power needed to drive the hoist. On generally similar lines *vertical* ash hoists have also been constructed.

Instead of a single unbalanced skip one may use a twin-skip hoist in which a loaded skip rises as an empty skip falls, thus balancing the two skips. The usual method of charging blast furnaces with iron ore, coke and limestone is somewhat similar in general principle, though not in detail. In Zimmer's Book (Chapter XXVIII) examples are given of actual blast-furnace hoists of both American and Continental designs.

A Novel Blast-furnace Hoist.—An unusual type of skip hoist [1] has been adapted to transport *coke* from a bunker and feed it into a blast furnace at a German steelworks. This is a special single-acting skip hoist having both a horizontal and an inclined track. The latter ends in a fork at the top, which tilts the full skip and lets the coke slide down a chute into the throat pan of a new blast furnace standing 25 ft. above the level of the old charging platform.

The controls to the electric winch are so arranged that the skip can stop for filling at any one of three outlets from the coke bunker. The winch is controlled from the same platform as are the bunker outlets. The coke skip has a capacity of about 11 cub. ft. It is stopped automatically at each loading point on the lower horizontal run and at the emptying position at the top.

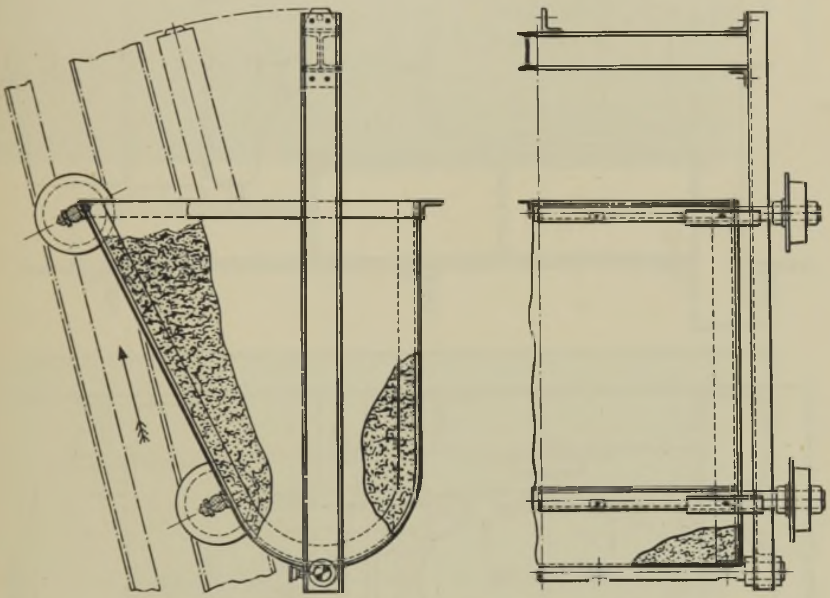


FIG. 154.—Skip and Yoke for Foundry Hoist.

A Foundry Skip Hoist.—Fig. 154 shows in detail the skip and its yoke, while Fig. 155 shows the driving gear of an inclined hoist made by the Ewart Chainbelt Co. Ltd., Derby, to handle the general refuse (including spent sand, ashes and slag) from an iron foundry at Luton. The working capacity

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[1] See *Mechanical Handling* of January 1939 for a brief illustrated account.

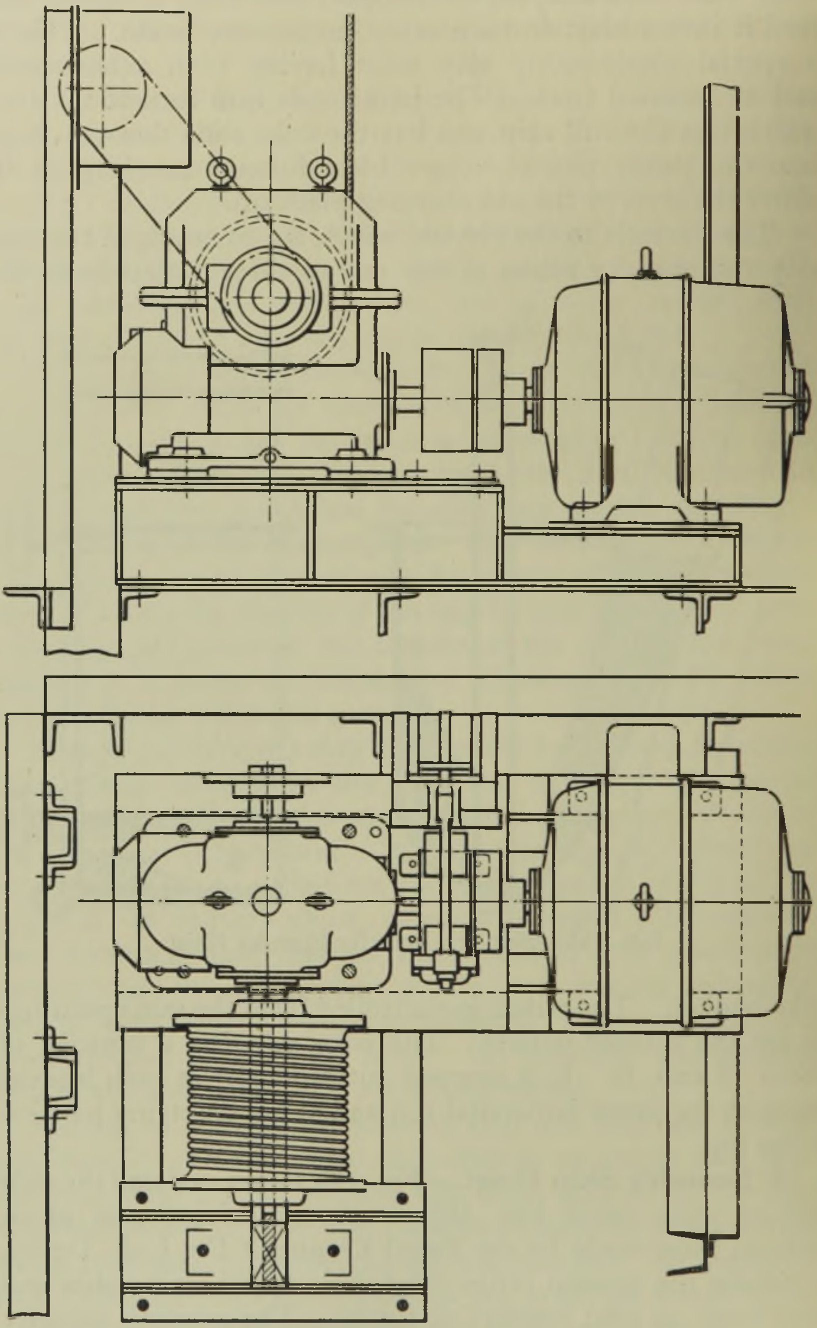
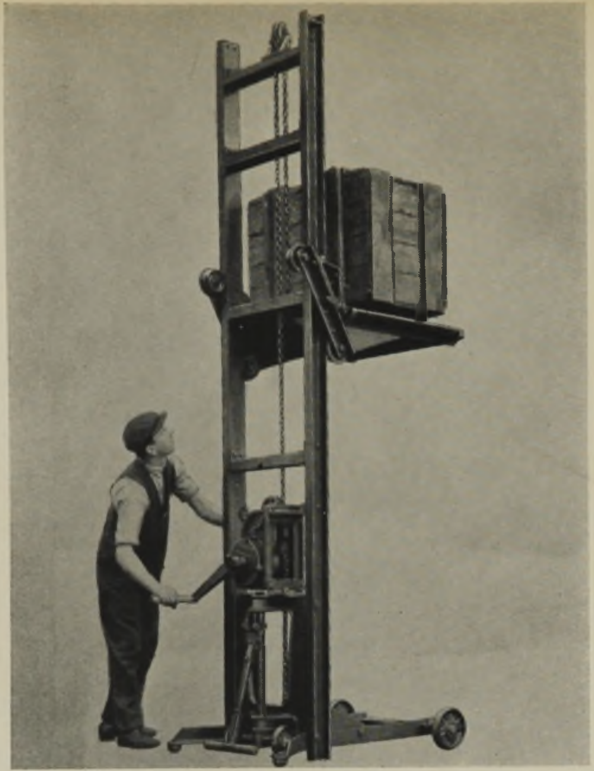


FIG. 155.—Driving Gear of Skip Hoist.

PLATE 47



Herbert Morris Ltd.

HAND STACKER FOR CASES.

Herbert Morris Ltd.

ELECTRIC VERSATILE CRANE.

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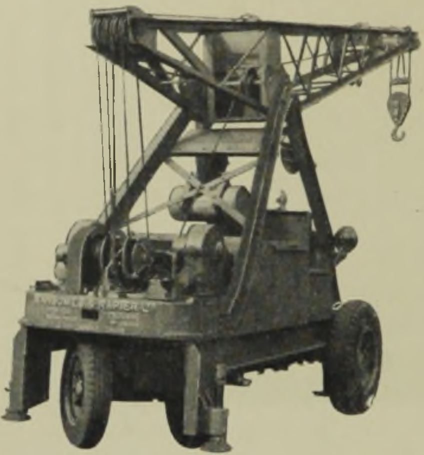
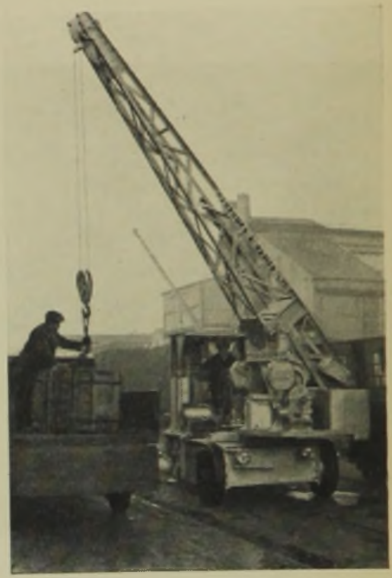
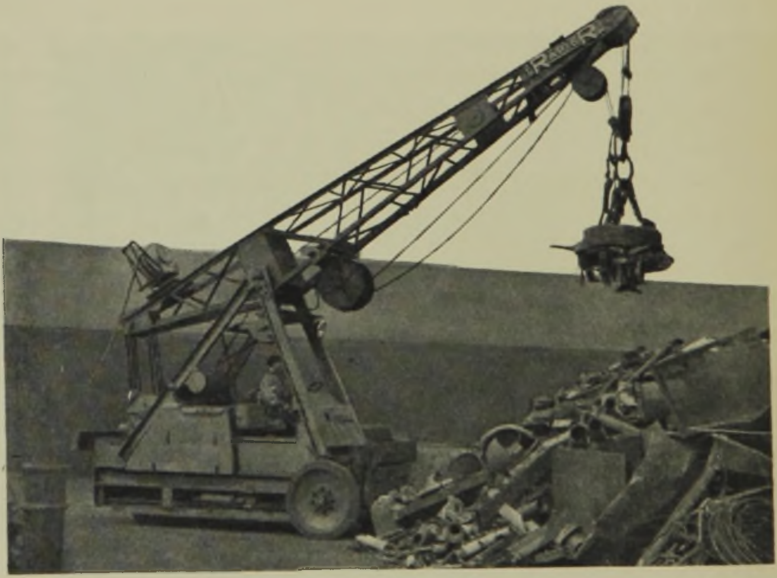
PLATE 48



REAR OF MOBILE CRANE.



SUPER-MOBILE CRANE.



Ransomes & Rapier Ltd.

STANDARD MOBILE MAGNET CRANE.

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of this machine is 10 tons per hour lifted 32 ft. high, the hoisting speed being 40 ft. per min. The skip load is 15 cwt. of refuse and the unbalanced weight of the skip itself is 7½ cwt.

The ½ in. diameter hoist rope, composed of six strands of 19-wire extra plough steel, is guided by 12-in. sheaves and winds on to a cast-iron grooved drum measuring 12 in. diameter by 12 in. wide between the flanges. This is driven by a totally enclosed motor of 6 H.P., running at 710 revs. per min. on a 500-volt direct-current supply, through a flexible coupling and a radicon worm-reducing gear, the whole being mounted on a fabricated steel bedplate. A magnetic brake with an 8-in. drum is fitted to the worm-shaft. Steel framing and guides are provided, as also a top housing, dust guards, platform, ladder and hand railing.

The 50-ton reinforced concrete storage bin receiving the foundry refuse has a steel-plate cover and is fitted with a suitably hinged discharge door at the bottom to facilitate the discharge into trucks of big lumps of slag, which are apt to cause trouble by blocking up the outlet.

The entire hoist is enclosed in galvanized, corrugated, steel sheets, 22-gauge thick, having 3-in. pitch corrugations.

The electrical control gear for this recent skip hoist comprises an automatic reversing contractor type starter, with 'start' and 'stop' push-buttons, a screw-operated limit switch to prevent overwinding and a 20-ampere, double-pole, ironclad switch with fuses.

COAL TIPS AND TRUCK HOISTS

End Tipper.—A simple form of tipper for the end discharge of coal trucks or wagons is shown in the line drawing (Fig. 156). The hinged cradle is lifted by means of a substantial strut in the shape of a special rack engaging with a pinion driven by an electric motor through suitable reducing gears. The cradle is made sufficiently long to prevent the buffers from fouling the rails when tipping at an angle of 55° with the horizontal. Hydraulic tippers enjoyed a long period of favour, before the advent of electrically operated tippers.

For coaling ships powerful plants have long been made capable of hoisting full trucks to a suitable height and end tip them into a capacious coal chute commanding the ship's hatchway. When trucks are of various patterns, they have to be turned over or inverted almost completely by means of a side-tipping truck hoist.

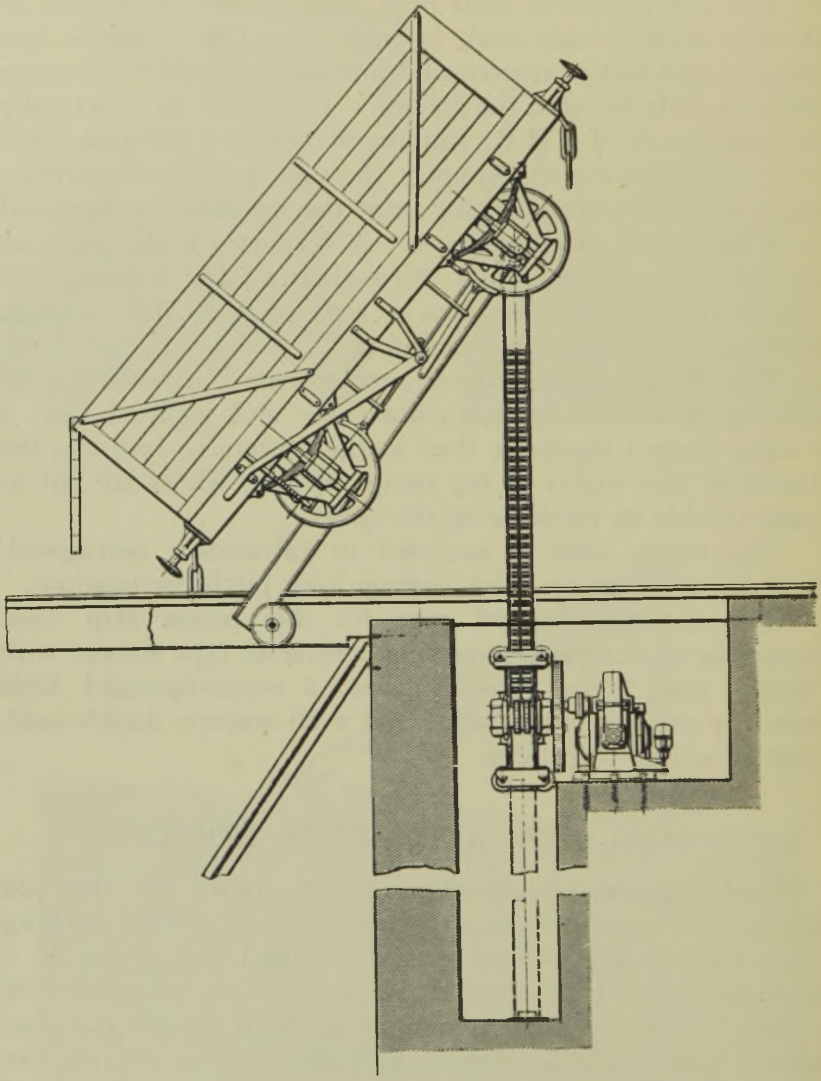

FIG. 156.—End Discharge Truck Tipper.

In respect of *mobility*, coaling jib cranes are more convenient than fixed coal hoists, as a crane can be readily moved along the quay to suit the position of the ship. Cranes, moreover, can be utilized for general purposes.

Hydraulic Tipper and Coaling Crane.—In Fig. 157 is shown[1] a hydraulic tipper discharging coal from a wagon into a 12-ton anti-breakage coaling box, an 8-ft. square skip fitted with four bottom doors. During the process of tipping, the coal is screened, the screenings falling into another and smaller box placed below the chute in the coaling pit.

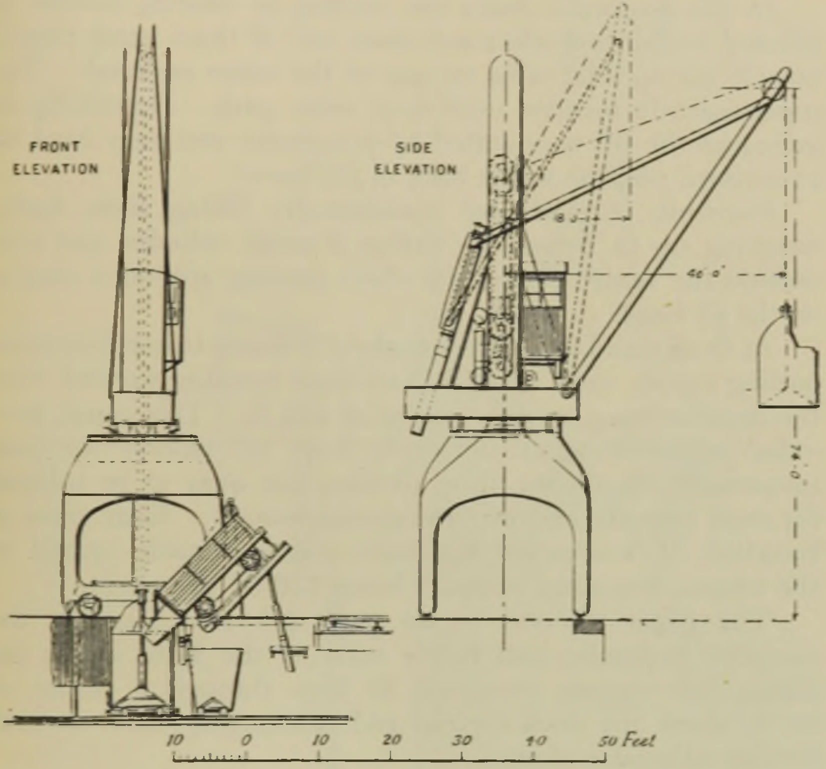

FIG. 157.—Hydraulic Coaling Crane and Tipper.

The operation of the anti-breakage coal box is interesting. The hoisting cylinder and ram of the 18-ton hydraulic coaling crane are placed in the tower, as also are the cylinder and ram for operating the coal box, which is secured by three chains, one of them being fastened to the middle of the cone of the box bottom. After the full box has been swung into position and lowered into the hold of the vessel, the water

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[1] From a paper by Henry S. C. Ree on " Mechanical Appliances Used in Shipping of Coal," read before the Institution of Mechanical Engineers at Cardiff, 1906.

pressure in the cone cylinder is released, when the conical bottom drops a distance of 30 in., and the coal is discharged in four directions. Meanwhile the box itself is supported by two side chains, and is now ready to be returned for refilling. This method of loading ships reduces to a minimum the breakage of coal in loading and trimming.

In this hydraulic crane the turning or slewing motion is effected by four cylinders and rams, two of them being placed outside the turning table on top of the crane pedestal. The superstructure revolves on a steel roller path. Derricking or luffing of the jib is operated by a cylinder and ram fixed in an inclined position at the back of the tower.

Provision is made for economically lifting light loads, weighing up to 2 tons, by fitting a small cylinder and ram outside the centre tower, the chain passing around a sheave on the jib head.

At the Roath Dock there are about a dozen 18-ton hydraulic coaling cranes, each travelling on lines running parallel with the dock coping, having a gauge of 21½ ft. This gauge provides sufficient space for two lines of railway to pass underneath the cranes, thus allowing the quay to be utilized for both imports and exports simultaneously. Each crane is travelled by a separate hydraulic engine suitably geared to the wheels, the water pressure being 750 lb. per sq. in.

The paper referred to on page 291 also describes the movable hydraulic coal hoists used at the Bute Docks for lifting full wagons weighing 23 tons through a height of 60 ft. above the dock coping, and discharging their contents into an adjustable chute.

Other movable coal tips are described in a paper on the mechanical appliances used in the shipping of coal at Penarth Dock, read at the same Cardiff meeting. These coal tips are direct-acting hydraulic hoists dealing with 25-ton gross loads. A three-cylinder hydraulic engine is utilized for raising the *point* of the coal chute, which is suspended by a wire rope, the *butt* end of the chute being raised or lowered by the cradle. Two cranes are fixed on each tip, one of 8 tons and the other of 4 tons capacity.

Electric Truck Hoist with Side Tipper.—Leaving these hydraulic coal tips for loading ships, we next turn to the consideration of a different type of coal hoist, electrically operated, as sometimes used in connection with large boiler-houses, and also adapted for locomotive coaling stations.

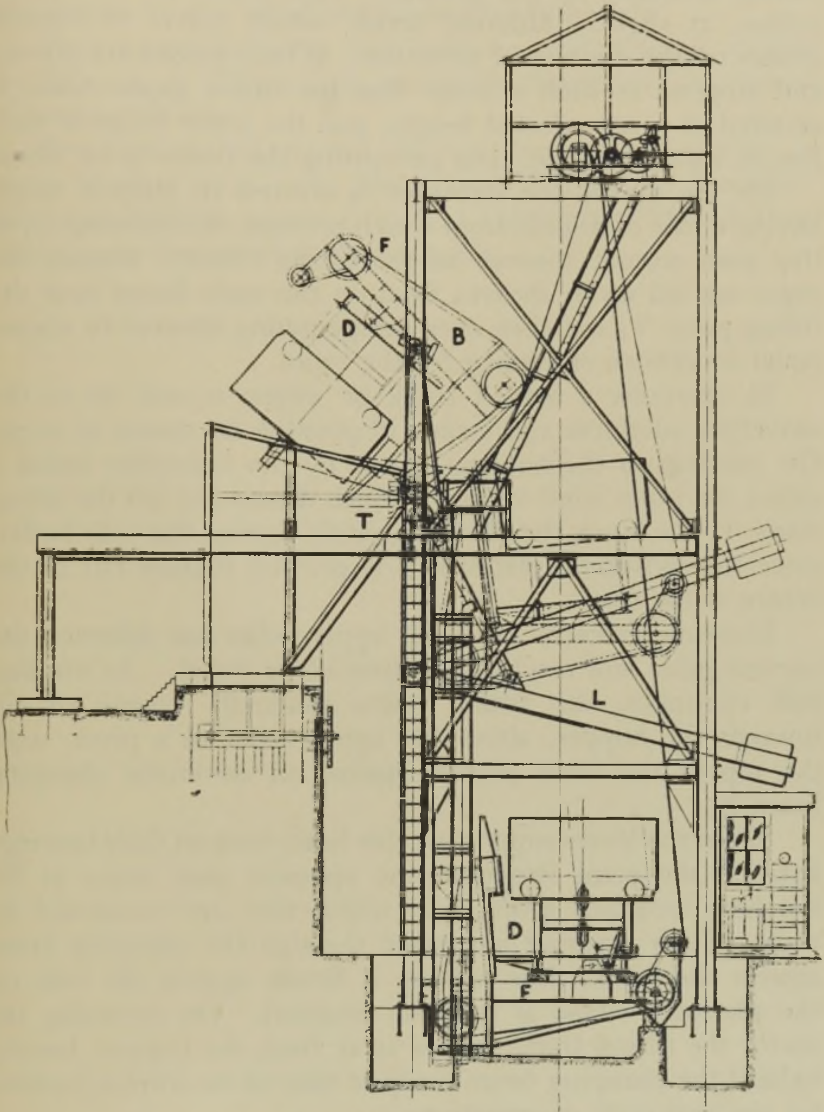

FIG. 158.—Electric Truck Hoist and Tipper.

This machine (Fig. 158) will hoist a full coal truck to the required height and tip its load *sideways* into a hopper raised well above the rail level.

Occupying the position of a portion of the rail track is a swivelling platform P, which is pivoted to a tilting frame F resting normally on the ground. This frame has two guide rollers, at slightly different levels, which travel in vertical guides on the main steel structure. These guides are curved and stopped at such a point that the upper guide roller is arrested at a pre-selected height, and the lower roller is then free to leave its guide, thus permitting the frame to be tilted.

On the top of the structure is erected an electric winch having a pair of drums, from which proceed two hoisting ropes that pass around sheaves on the tilting frame; whence the ropes are led up to sheaves fixed on the main frame near the tilting point T, and then over compensating sheaves to ensure equal conditions of loading for the ropes.

In *operation* a loaded truck or wagon is run on to the swivelling platform and locked in position by means of stops. On starting-up the hoisting motor by the controller inside a cabin, the ropes wind on to the winch drums and lift the tilting frame F, the truck then leaning gently against the side buffer, since the swivelling platform P is pivoted slightly out of the centre of the track.

Hoisting proceeds until the upper roller has followed the curved guide and reached the limit of its travel. As winding still continues, the tilting frame gradually begins to tilt towards the hopper, about the upper roller as a pivot, until the top of the truck presses against an automatic clamping beam B.

When the levers supporting this beam turn on their bearings fixed to the main structure, the opposite ends begin to lift the long weighted lever L to which they are connected by rods. Their pressure is exerted through the clamping beam against the truck, thus holding it firmly against the rails on the platform whilst it is being emptied. On reversing the motor the tilting frame moves away from the hopper, leaving behind the clamping beam ready to take up its correct position for the next cycle of operations.

This position is settled by the weighted levers bringing the point of support for the coupling rods on the beam levers into line with their fulcrum on the main frame. When the *lower* roller enters its vertical guide, the *upper* roller follows downwards along its curved guide. Then the tilting frame carrying the empty wagon descends, and the swivelling platform takes up its alignment with the railway track. After stopping the motor, the locks or rail stops are opened, and the empty truck is displaced by another full truck.

Plate 43 (B) depicts a coal hoist on this principle erected by Babcock & Wilcox Ltd. at the Southampton Corporation Electricity Works.

For further information on coal tips, reference may be made to Zimmer's " The Mechanical Handling of Material," Chapter XXXV, where British, Continental and American designs are described at some length.

CHAPTER XXIV

STACKERS OR TIERING MACHINES

FOR piling bags to a great height in orderly sequence, so as to utilize a store or warehouse to its utmost capacity, special portable machines termed *pilers* are much employed. These are often inclined continuous conveyors, though intermittently working vertical hoists are also available, either for hand or power operation. Similar machines styled *stackers* are adapted for handling cases and bales economically.

When using a modern electric stacker the whole process of loading, hoisting and stacking a box can be performed in less than half a minute, the actual time depending on the height of lift. It is estimated that one man with a stacker will do as much work as six men without its aid, and that the wages saved would pay for the machine in six months.

One type of tall *vertical* stacker is really a portable reversible finger-tray chain elevator, mounted on wheels and driven by a reversible motor. This machine is utilized both for building up a stack and for lowering packages from the stack to the floor, hinged tables being employed.

An example of an *inclined* continuous stacker fitted with chains and slabs is shown in Fig. 159, receiving *cases* from a gravity roller runway and lifting them to a variable height in order to build up a stack of cases with a minimum of labour. Another example of a continuous machine of large capacity for piling *bags* is fully described and illustrated in Chapter VI of my " Conveying Machinery."

Such a machine, however, is relatively expensive and takes up a good deal of floor space, which is not always available. In that case the intermittent vertical type of stacker, which occupies less floor space, is very suitable for filling up a warehouse with boxes and such goods as bales of cotton and wool. In warehouses with low head-room only a short type of machine is possible, and a hand-operated stacker may meet

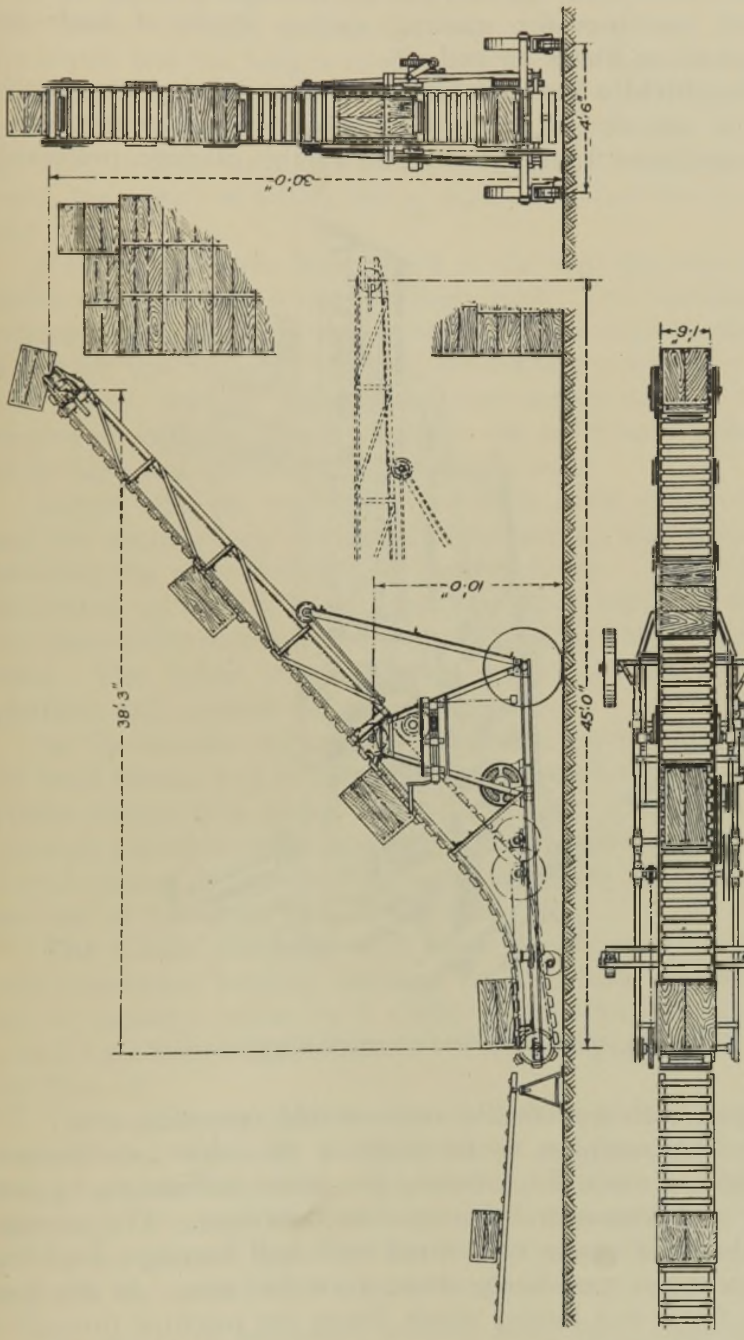

Fig. 159.—Stacker for Cases, in Plan and Two Elevations. (From Zimmer.)

the needs for loads up to 10 cwt. Examples of some simple manual machines for stacking various kinds of loads are illustrated on Plates 45 and 47.

Woodfield's Vertical Stacker.—Fig. 160 is a perspective view of this design of tiering machine, which consists of a telescoped steel frame mounted on a stable carriage, preferably equipped with a turntable and suitable operating gear. To enable the machine to function in the older warehouses, provision is made for lowering the frame sufficiently to pass under roof trusses and through low doorways. The carriage has wheels of castor type fitted with ball bearings, enabling the stacker to turn freely about a vertical axis. At the foot of the frame is a motor, which drives the machine through a chain and gearing.

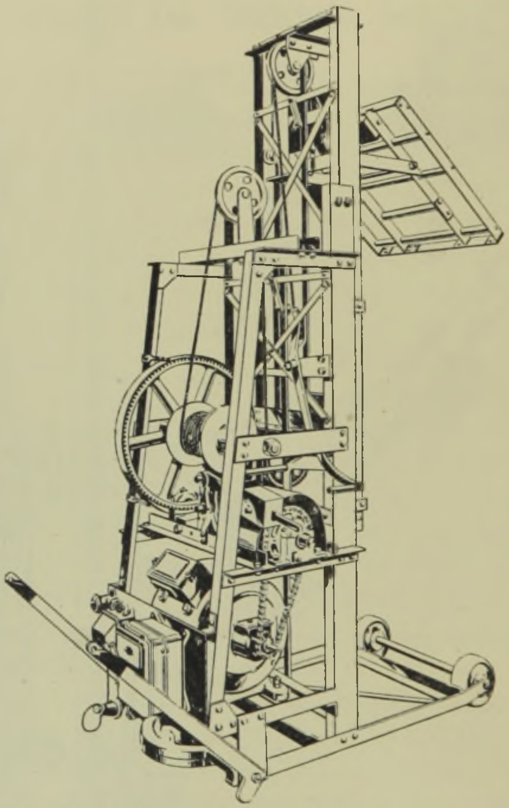

Fig. 160.—Woodfield's Vertical Electro-Stacker.

The hoisting drum is driven through a hand clutch and spur gears. A light pressure on the operating lever engages the clutch and the load is raised. When this has reached the required height the lever is released and its own weight then suffices to sustain the load on the band brake. Gravity lowering is done on a free barrel by slightly raising the hand lever, the speed of falling being then controlled by the lever and brake.

A tilting platform is provided at the top, the only attendance needed being a man at floor level. On disengaging a locking finger, the platform is tilted and the load thrown off. A similar machine can be used for loading a van or a lorry with cases. In lofty warehouses much higher stackers can be employed with advantage, raising up to 1-ton loads over 20 ft. high at a speed of 60 to 80 ft. per min.

Larger stackers or tiering machines have *hinged* frames and are mounted on under-carriages having ball races, thus enabling the superstructure to revolve freely. The load can be picked up from a loading platform level with the floor at the front of the machine and dropped on either side at a higher level. The driver stands slightly higher on the operating platform and controls the various motions.

In the smaller stackers, slewing and travelling are done by hand labour, but in the large machines all the motions are power-driven, thus saving time and labour. Current is taken through a flexible cable from plug switches placed at intervals. Petrol-engine drives are not favoured inside warehouses on account of the fumes and the fire risk.

The Collis Stackers.—Of later design are the efficient and convenient vertical stackers, ranging from 2½ cwt. to 1 ton in capacity, made by J. Collis & Sons Ltd., of London, which have been widely adopted. Two examples are illustrated on Plate 46.

The Collis portable stacker is built with either a rigid welded steel frame or a *hinged* frame at pleasure, the latter being needed only when the machine has to pass through doorways or under low beams or other obstructions.

In the *manual* type [1] a thin oil is forced into a hydraulic cylinder by means of a simple reciprocating pump operated

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[1] An example is permanently exhibited in the Home Office Industrial Museum, Westminster.

by a long handle, this handle being also utilized for hauling the stacker along the floor. The lifting speed is increased by introducing multi-fall wire-rope sheaves between the ram and the table carrying the load. Ball bearings are fitted throughout. The mechanical efficiency is said to reach 90 per cent., which is much higher than is obtainable with a spur-geared hoisting winch. Hence a small force applied at the end of the long lever handle on the down stroke will lift a good load.

Also there is no danger of the loaded table falling too rapidly. The lowering speed can be adjusted to a nicety. It is fast when the table is empty and slow when loaded. The load is securely held at all times, the ram acting as a hydraulic brake.

In the *electric* type of Collis stacker a vertical spindle motor is geared to an enclosed pump feeding the hydraulic cylinder. Just below the pump is a capacious oil-receiver, from which the pump suction is taken. The electric stacker is naturally much more rapid in operation than the manual stacker, the usual lifting speed being 30 ft. per min. It should certainly be adopted for loads exceeding 10 cwt. Push-button motor control is provided.

When it is necessary to revolve a load, the lifting table is fitted with a turntable. This is simpler and cheaper than using a revolving stacker when loading from the end of the table and discharging from the side. A common size of table is 36 in. long by 27 in. wide, and the wheels are made from 6 to 9 in. diameter. An optional fitting is an automatic cable safety device to hold the table secure in case the wire rope should break.

CHAPTER XXV

LIGHT MOBILE CRANES

Of recent years there have been big developments in the design and application of light portable cranes of remarkable mobility, whose lifting capacities range from 1 to 6 tons. Combinations of cranes with trucks of various kinds have become common, some being mounted on low trucks or bogies with solid tyres and others mounted on high motor trucks equipped with big pneumatic tyres suitable for long-distance work, as in laying pipe lines abroad.

In the case of a petrol or a diesel electric lorry crane the engine is coupled up to a variable-voltage dynamo and can be speeded up to supply current for the hoisting, the derricking and the slewing motors. Thus any or all of the motions can be operated at the same time, at speeds determined by the position of the accelerator pedal in the driver's cab, just as in motor-car practice. Alternatively the driver may sit on the revolving superstructure, where he has a better view of the load on the hook.

The Rapier Truck Mobile Crane.—The useful combination machine shown in Fig. 161 is designed to satisfy the need for a carrier truck that can load and unload heavy pieces quite independently of a separate crane. It can pick up and deliver goods up to a ton in weight at any part of a level factory or warehouse or yard. The power supply is a petrol engine coupled to a dynamo. The machine is self-contained and has a separate electric motor for each motion. All four motions are controlled from the driver's seat and can be worked together. Simple tiller steering with a wide angle of lock enables this crane to manœuvre about yards and gangways with the utmost facility. The full load may be carried either on the crane hook or on the truck platform. See Plate 44 (B).

A special jib 12 ft. long for this crane can be built, in aluminium alloy, light enough to be lifted by one man, though steel jibs are naturally much more usual. A telescopic jib enables a crane to make an occasional high lift without being unduly encumbered by an inconveniently long jib interfering permanently with its general mobility. The special telescopic jib can be extended to give a *height* of lift of 16 ft., while loads of 7½ cwt. can be lifted at 15 ft. radius.

The trucks are made with either two-wheel or four-wheel steering. Solid rubber tyres are fitted to the travelling wheels. The normal truck speed is 6 miles an hour light and 4 miles an hour when loaded, but the actual speed varies with the state of the road. The complete machine weighs 3¼ tons, while the overall dimensions of the truck are 12×4 ft.

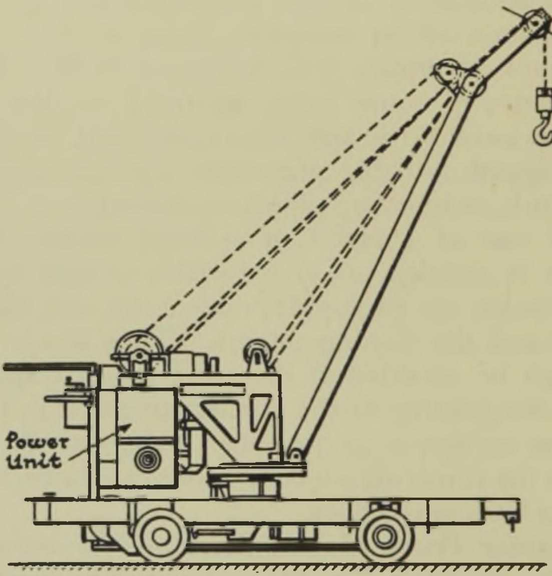

FIG. 161.—Light Carrier Truck Crane.

The Rapier Standard Mobile Crane outlined in Fig. 162 is made in four sizes, a common size being capable of lifting up to 3½ tons at a radius of 11 ft. 9 in. on a two-part rope block. It can also lift up to 5 tons at a radius of 6 ft. 9 in., when the rope is reeved through a four-part block, ingeniously arranged by hooking the two-part block back to the jib. In working order such a crane weighs about 8½ tons.

This crane can be turned about easily in a gangway 14 ft. wide and can travel along a gangway only half that width.

It is self-aligning to its load, so that if employed to drag the load it will turn its wheels towards the load and there is no fear of the crane tipping over sideways from a lateral pull on the hook.

The crane has four rubber-tyred road wheels, two being mounted on a fixed axle at the front. The other two, the driving and steering wheels, are mounted on an articulated castor, pivoted to a king-post in the tail of the machine, so that the weight is borne equally by the two driving wheels, which adjust themselves to uneven ground. Thus the crane is supported on two front wheels and the rear castor, and is therefore stable even on rough ground. This castor can be turned by a steering wheel through 90° on each side of the straight-ahead position, thus allowing the crane to travel round curves of short radii or to slew around the centre of the front axle.

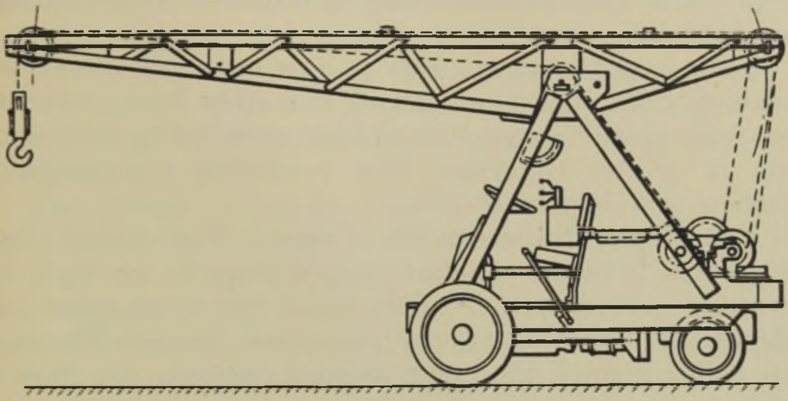

FIG. 162.—" Rapier " Mobile Crane.

The motive power is petrol-electric or diesel-electric at pleasure. Separate motors drive the hoist, the derrick and the travelling motions, which can all be worked simultaneously.

The speed of each motion is controlled by the engine accelerator pedal. The hoist and derrick motions have high-efficiency enclosed worm-gear drives. Self-adjusting electric brakes are fitted to give load protection in the event of the current failing, and limit switches are provided as a protection against overwinding.

A separate series-wound motor drives each of the two castor wheels. These motors are wired in series, giving a perfect differential drive when steering round a curve or running on rough ground. The front wheels can be fitted with pneumatic tyres, which facilitate travelling over rough or soft ground.

Special Attachments for Mobile Cranes.—An ingenious parallel-motion jib can be applied, enabling the crane to be used as a stacker for cases, barrels, pipes or rolls of paper. This comprises a main jib plus a pivoted end piece, which can be set to give parallel motion until the jib is horizontal and thence as a straight jib, thus giving a higher lift.

A folding apron or platform projecting at the front of the truck can be fitted to enable loads on it to be travelled through low doors into a warehouse.

Other possible attachments to this crane are *shovels* for handling coke, coal, sand, gravel and other loose materials, also *grabs* of various types for picking up anything from sugar beet to granite chippings, thus producing a combination machine of wide general utility.

The Rapier Super-mobile Crane.—This design (Plate 48) differs from the standard mobile crane in having a full revolving superstructure. This makes the 6-ton crane well adapted for handling railway containers, because the short tail radius permits the crane to work between two lines of rails or to load from truck to lorry without moving the road wheels carrying the substructure. This new feature, however, involves considerable extra expense. The weight of a 6-ton crane in working order amounts to fully 19 tons, while the 5-ton size of super-mobile crane weighs 12 tons, which is some 50 per cent. heavier than the standard 5-ton mobile crane.

The Rapier Friction Crane.—A light rapid 2-ton jib crane has been designed by Ransomes & Rapier Ltd., of Ipswich, which can be driven by either a paraffin engine, a diesel engine or an electric motor. For this handy crane there is also a choice of four different mountings, namely: flanged rail wheels, rubber-tyred road wheels, lorry mounting and caterpillar tracks or crawlers.

The hoisting speed is 65 ft. per min. and the fastest travelling speed 2½ miles an hour. At the greatest radius of 25 ft. the height of lift is 12½ ft., while the total weight of the crane in working order is 6½ tons. The crawler crane can lift 2 tons at 12 ft. radius, giving a moment of 24 ton-ft.

This crane has a fully revolving superstructure and all the motions are independent. In order to relieve the mechanism of needless shocks and to smooth out the irregular driving torque, a *fluid coupling* is preferably fitted between the engine and the main driving shaft.

The crane is suitable for light hold-rope grabbing operations and there are two travelling speeds. The steel framing is of welded or fabricated construction, giving sufficient strength without needless weight.

In the crawler type of mounting enough small rollers are fitted between the driving sprocket wheels and the tension rollers to support each crawler pad and prevent buckling. The crawlers spread the load well over a large area and give a low ground pressure. Steering is effected by driving one crawler only, while the other side is locked to the frame by means of a dog clutch.

The Morris Versatile Crane.—A 2½-ton mobile crane made by Herbert Morris Ltd., of Loughborough, is pictured on Plate 47. Here the power unit is either a petrol or a diesel engine, coupled to a dynamo supplying current to the motors for driving the various motions, all of which are controlled by a single pedal through a selector box.

As big pneumatic tyres are fitted to the wheels, this crane will travel well over rough ground, the road adhesion being proportional to the load on the hook. Steering is controlled by a hand wheel through a rear castor. This is an extremely lively and versatile crane, capable of many applications.

CONCLUSION

In the preceding pages consideration has been given to all kinds of cranes both old and new, big and little, fixed and mobile. Some features have been gone into pretty fully whilst others have been only lightly touched upon.

Nevertheless sufficient has been said and pictured to indicate the great variety and economic importance of hoisting machinery in general, and also to give useful help and guidance to both students and practitioners desirous of following up the subject in its fuller developments. Much additional information will be found in the appended bibliography.

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OTHER SOURCES OF INFORMATION

From time to time articles of great technical value to crane designers and users appear in several weekly and monthly periodicals, such as *The Engineer*, *Engineering* and *Mechanical Handling*. The Transactions of several engineering societies at home and abroad also contain priceless mines of valuable information which are ever growing richer.

Finally, helpful descriptive literature in the form of catalogues is issued by the following and other well-known engineering firms, some of whose products have been illustrated in the foregoing pages : Sir William Arrol & Co. Ltd., Glasgow ; Babcock & Wilcox Ltd., Renfrew ; Joseph Booth & Bros., Rodley, Leeds ; Butters Bros. & Co., Glasgow ; J. Collis & Sons Ltd., London ; Cowans, Sheldon & Co. Ltd., Carlisle ; Ewart Chainbelt Co. Ltd., Derby ; Industrial Brownhoist Corporation, Bay City, Michigan, U.S.A. ; Herbert Morris Ltd., Loughborough ; Priestman Bros. Ltd., Hull ; Ransomes & Rapier Ltd., Ipswich ; Thomas Smith & Sons, Rodley ; Stothert & Pitt Ltd., Bath ; Strachan & Henshaw Ltd., Bristol ; and The Rapid Magnetting Machine Co. Ltd., Birmingham.

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