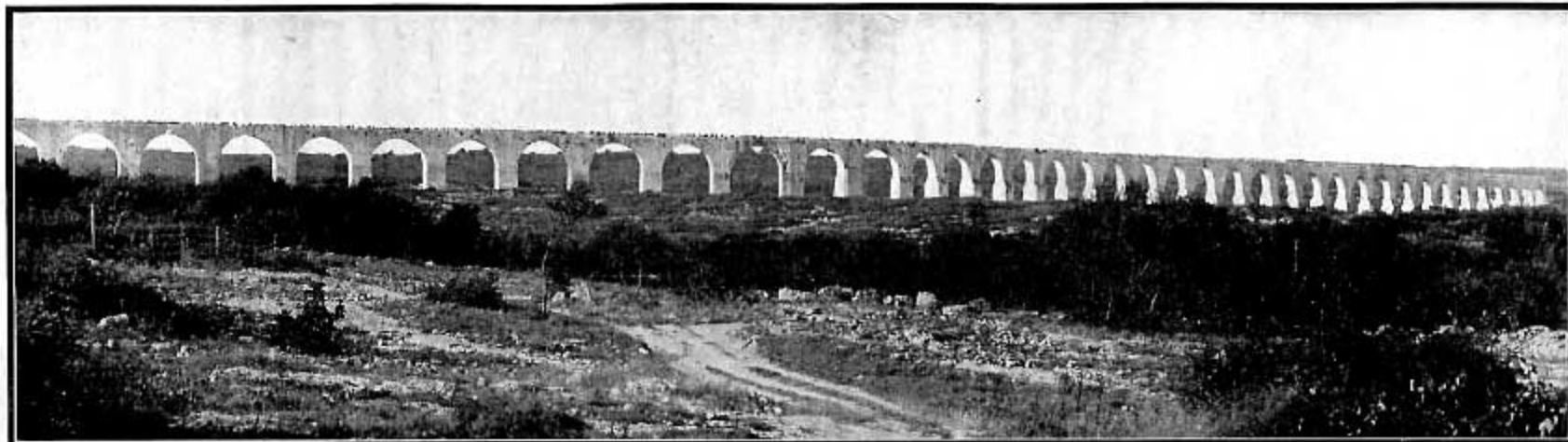


The **MECCANO** **BOOK OF ENGINEERING**



PRICE
THREEPENCE



Engineering of 2,000 years ago! This aqueduct still standing in France is a splendid example of the skill of the Roman engineer and is evidence of his great share in the spread of civilisation

Foreword

The immense popularity of the *Hornby Book of Trains*, which made its first appearance in 1925, has led to a widespread demand for a similar production dealing with engineering in general and Meccano engineering in particular. We have therefore decided to publish the "*Meccano Book of Engineering*."

In the following pages we deal with engineering in its widest aspects. From the earliest times, civilisation has been dependent for its advance upon the engineer. The nations that have made the greatest progress have been those that not only had the cleverest engineers, but also, realising the immense importance of their work, have availed themselves of the ever-increasing facilities it afforded.

Perhaps the most outstanding feature of the work of the engineer has been his development of means of communication. Roads and waterways have been vitally important to civilisation, both as highways along which merchandise of all kinds has been carried and as channels along which easy and rapid interchange of ideas among developing races has been effected. This book is devoted largely to the consideration of the problems involved in this branch of engineering.

In providing communications by road the necessity for bridges must have been felt even by prehistoric man. The fact that the art of the bridge-builder is of great antiquity is proved by the existence of crude stone bridges, such as the ancient structure across the River Dart at Postbridge in Devonshire, and the still cruder rope bridges that are even now to be met with in wild regions of South America and Central Asia. The immense growth of traffic by road and rail in recent times has resulted in the building of bridge after bridge, and as an example of present-day practice we tell the story of the building of the Quebec Bridge.

Inland waterways, too, have played an extremely important part in providing easy communication. It is true that the smaller canals, having outlived their period of usefulness, have fallen on evil days, but their value to commerce before the development of railways can scarcely be over-estimated. To-day interest centres mainly on the great ship canals of the world, and we describe how the construction of these has been facilitated by the use of dragline excavators—giant machines that tirelessly eat their way into the ground, doing as much work as many hundreds of men could do with pick and shovel. These mighty digging machines have been of value also in the carrying-out of irrigation schemes.

Day by day vast quantities of merchandise are sent by road, rail, or canal to the most convenient seaport for shipment abroad, while at the same time ships are arriving with cargoes from all parts of the world. Shelter must be provided to enable the loading and unloading of vessels to be carried on in all weathers, and we show how the use of Portland cement and cranes of enormous power has enabled the engineer to build up structures to defy the violence of the sea.

Finally, we show that, in spite of the enormous progress that has already been made in engineering, the possibilities are scarcely touched, and we visualise some of the developments that probably will take place in the future.

We take this opportunity of acknowledging the valuable assistance we have received in the preparation of this book from the Dominion Bridge Company Ltd., Montreal, in regard to the building of the Quebec Bridge; Ruston & Hornsby Limited, Lincoln, dragline excavators; and Stothert & Pitt Limited, Bath, block-setting cranes.

The Engineer and Civilisation

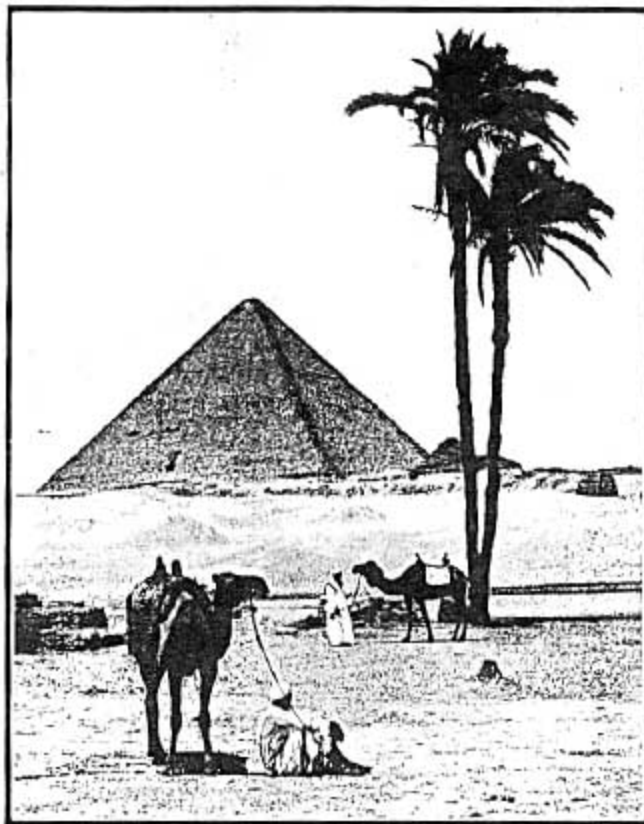
THE story of civilisation is very largely the story of engineering; in fact it is not too much to say that no nation has ever become civilised without the aid of the engineer. The very earliest beginnings of civilisation appear to have been associated with engineering, for there is good reason to believe that crops of grain for food were raised in prehistoric days on terraces that were cut out on the hillsides near rivers in order that they might easily be supplied with water by means of crude lifting or pumping appliances. The irrigation systems thus set up were the beginnings of the mighty developments that are seen at their best to-day in Egypt and the Sudan, where huge dams have been built to enable the waters of the Nile to be used for renewing the fertility of the soil.

At later periods the nations that rose to greatness were always remarkable for some form of engineering skill. The Egyptians were famous for their Pyramids and their wonderful temples, practically all of which were examples of engineering ability of a very high standard. The largest of the Pyramids, indeed, still possesses the distinction of being the greatest mass of masonry ever erected. Most of the stones of which it is built weigh from 50 to 60 tons, but in spite of their size many were actually raised to a height of 500 ft. above the ground after having been transported from far-distant quarries.

An even more surprising example of the manner in which the Egyptians handled large masses of stone in building is furnished by the stone out of which a statue of King Rameses II was hewn. This was discovered at Thebes, hundreds of miles from the nearest quarry of the red granite of which it is composed. It is 60 ft. in length and its weight has been calculated at not less than 887 tons. The quarrying and transport of such a huge mass would present a formidable problem to the engineer of to-day with all his wonderful machinery and appliances, and it is little short of marvellous that the Egyptians, with their crude mechanisms, should have been able to carry out such a gigantic task.

An even more remarkable instance of the engineering capacity of ancient peoples is furnished by the huge block of stone, 69 ft. in length and estimated to weigh 1,500 tons, that has been uncovered at Baalbek, Syria.

The Romans undoubtedly owed a great part of their supremacy to the skillful use they made of engineering principles in the construction of large war machines of the catapult type and in the fortification of their camps. Their engineers were



One of the engineering wonders of a past civilisation. The Great Pyramid of Cheops is the largest mass of masonry in the world. Many of the blocks of stone of which it is built weigh 50 to 60 tons, while the highest stones were raised nearly 500 ft. above ground level.

particularly successful in road making, and the straightness and the wearing qualities of a Roman road are now proverbial. Every country they conquered and occupied was quickly covered by a network of splendid roads, many of which still exist or have become the sites of modern roads. Other signs of Roman occupation are to be seen everywhere in the ruins of the magnificent buildings, bridges and aqueducts that they constructed.

Roads and bridges undoubtedly provided the engineers of early days with their chief opportunities. Both have always been of vital importance in making communication easier and in assisting the development of trade and the opening out of the natural resources of a country. The Romans realised this fully and the road engineer of a province of their vast empire was a very important official.

In Britain roads of a kind had been constructed even before the Romans conquered the island. In Cornwall, for instance, there were tracks made of stone blocks over which most probably tin was carried to the coast where the Phœnician traders awaited it, while similar roads existed in many other parts of the country. The Romans developed and extended the road system extensively, partly to enable their armies to make rapid marches from one fortified camp to another, and partly also to open up the country for trade purposes. Examples of the roads constructed in Britain by the Romans may still be seen, as the efficient drainage provided and the hard nature of the stone used for paving made them extraordinarily durable. No finer roads were built, in fact, until the time of the famous engineer Telford, nearly 2,000 years later.

After the Romans left Britain the wonderful buildings they had erected were treated as quarries, the stone being removed for use in the erection of meaner buildings, and most of the roads fell into disuse and gradually became covered with earth. The partial abandonment of these products of engineering skill was due to the barbarism and lack of understanding of the

Anglo-Saxon invaders who soon descended upon the unprotected country, and it was not until these people in their turn began to pay attention to similar necessities that civilisation in Britain moved forward once more.

Progress was very slow until the beginning, about 150 years ago, of the great engineering age. The first important step was taken by Watt, who so much improved the crude steam engines already in use that he is popularly regarded as the

Steam Power changes the World

actual inventor. After Watt had made this ample source of power available, amazing strides were made in industry and commerce, most of the credit for which must be attributed to the great engineers.

The most familiar of the uses to which the steam engine was put was in the construction of locomotives. As this development came at a time when a splendid road system had been created by the labours of Telford and his successors, steam locomotives were at first planned to run on the roads. In the meantime, however, railroads had been made in various parts of the country, on which wagons were drawn by horses, and the suitability of these for the new method of haulage soon became evident. Largely through the labours of George Stephenson and his associates in the north of England, and of the pioneers of the Baltimore and Ohio Railway in America, railways as we know them to-day came into existence, and thus the engineer took a great step forward in the work of making communication easy.

Steamships also became of commercial importance. They grew more numerous and progressively larger, until their greater speed and capacity for carrying cargo, together with their comparative independence of weather conditions, enabled them to displace sailing vessels almost completely.

These great engineering developments were productive of results in all parts of the world almost immediately. The steamship brought the old world and the new into closer contact and knitted the various parts of the latter together. Britain especially benefited by the change, as the times required for the journeys to Canada, South Africa, Australia, and New Zealand were greatly shortened. This led to a more rapid development of the resources of these great countries, as the rate of settlement was greatly increased.

Railways also played a great part in the exploitation of the natural wealth of these and other partially developed countries. This was particularly noteworthy in Canada, where far-seeing minds called on the engineer to construct a line to stretch across the prairies to the Pacific

Railroads make Western Canada

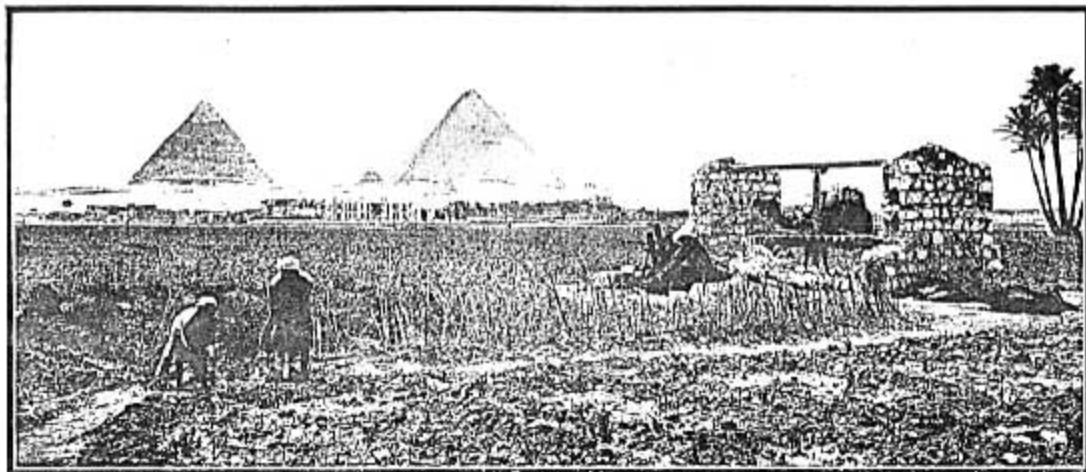
Coast. A similar scheme had already been carried out further south, and it was thought that the new road would at least make communication between the settlements on the east and west coasts of Canada easy, as the earlier road had already done for those of the United States.

Actually the successful completion of the Canadian Pacific Railway, as the new line was called, did far more. Prior to its construction the easiest route to Winnipeg and the Western Provinces of Canada led through the territory of the United States, while British Columbia was also more closely in contact with the latter country than with the rest of Canada.

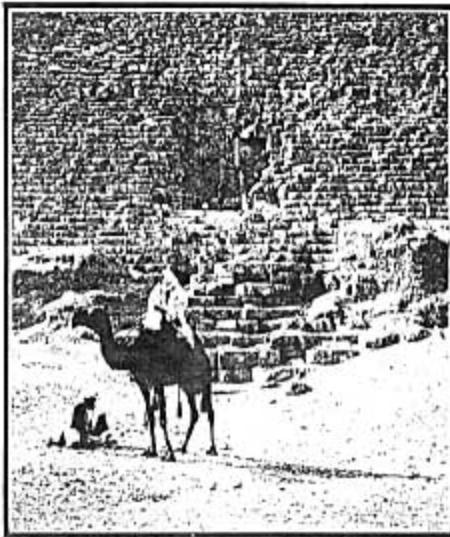
The railway opened out an easy route north of the Great Lakes and bridged the Rocky Mountains, thus making Canada for the first time a really compact and self-contained territory.

In addition the railroad increased the rate of settlement enormously by providing access to the rich prairie lands and a means whereby the grain that they produced could be exported. The process has since been continuously accelerated by the construction of a second trans-continental railroad and of numerous branch lines. It is no exaggeration to say that Western Canada has been made by engineering, for it could not have become the thriving region that it now is if the railroads had not been constructed.

Examples of the immensely important part played by railways in the development of new countries could be given from almost all quarters of the earth. The first question raised by any country desiring to bring new regions within the sphere of civilisation is invariably that of the construction of a railroad. This holds good in all climates. Kenya in the tropics, and Manchuria in the extreme north of China, are both undergoing development along newly constructed railroads, and into the dense forests of the Congo and of Brazil, the northern prairie lands of Canada, the fertile valleys of China, and the ancient and productive countries in the hinterland of West Africa, railways are being pushed forward as heralds of civilisation.



(Above) Crude irrigation in Egypt under the shadow of the Pyramids. The large wooden wheels turned by a camel or bullock raise water in earthenware pots, a method that has been used for thousands of years. (Below) This photograph of the entrance to the Great Pyramid gives a good idea of the size of the building and of the magnitude of the task of its builders. It has been calculated that it contains 2,300,000 blocks of stone.

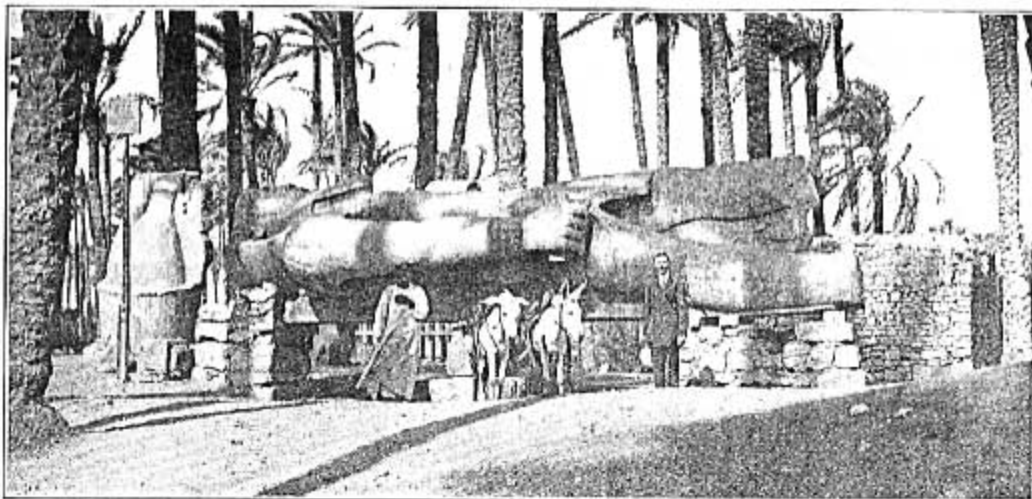


Waterways that Link the Oceans

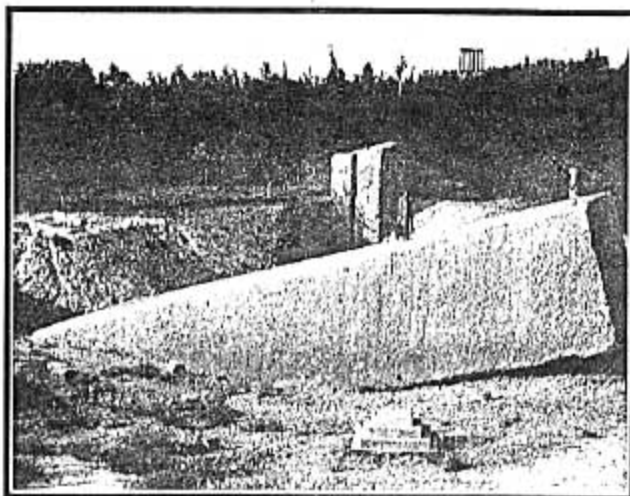
The extension of railroads to hitherto inaccessible parts of the earth has not been carried out easily and it has been necessary to learn many new methods of bridging rivers and boring tunnels through mountain ranges. Some of the greatest feats in this direction deserve mention as important agents in the engineer's conquest of the world for civilisation. An outstanding example of a bridge that opened an enormous field for exploitation is that over the Zambesi River near the Victoria Falls. It made possible the extension of the railroad to the valuable gold and copper mines of northern Rhodesia and the borders of the Congo Free State.

Other instances of the influence of the engineer are provided by the Suez and the Panama Canals. Until the former was opened the most convenient route from Britain to India was around the Cape of Good Hope, and Calcutta was reached as easily as Bombay. The shortening of the journey benefited Indian trade and commerce considerably, a fact that was made evident by the phenomenal growth of the port of Bombay. This city displaced Calcutta as the principal port of entry, but nevertheless Calcutta continued to grow and flourish. The Suez Canal in fact made Bombay in exactly the same way as the Canadian Pacific Railway made Western Canada, but in neither case did any other district suffer from the development.

The Panama Canal is proving equally well that the work of the engineer is one of the chief factors in developing and extending civilisation. The mere fact that it is no longer necessary to make the dangerous voyage around Cape Horn is sufficient justification for the existence of the canal, and marks the engineers who constructed it as benefactors to humanity. Beyond this, in the comparatively few years of its existence the canal has already led to a great increase in the importance of the countries on the western slopes of the Andes and of the Rocky Mountains. The



(Above) The Statue of Ramses II found at Thebes. It was carved from a single block of granite transported from Assouan, hundreds of miles away, in spite of its weight of 887 tons. (Below) The largest block of stone ever quarried. Its estimated weight is 1,500 tons, and we can only surmise how it was handled by the ancient inhabitants of Syria, where it was found.



The Era of Electricity

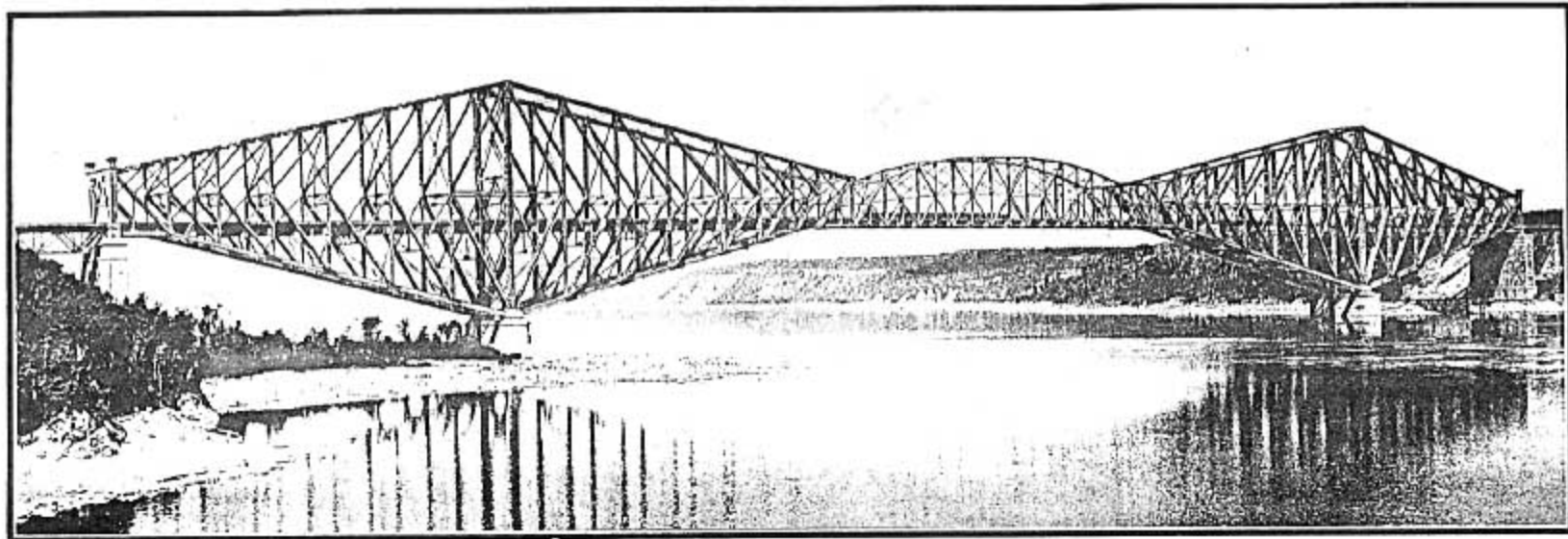
astounding growth of Los Angeles is a striking example. This is due almost entirely to its growing value as a seaport. In the United States it actually ranks second to New York, a position that it owes to its favourable situation as the nearest port in California to the Panama Canal.

Along with the development of the railway and the steamship during last century came the application, on a continually increasing scale, of steam power in industry. Spinning and weaving in all their branches benefited greatly by this, while production in iron and steel-works increased enormously in attempts to cope with the demands occasioned by new applications of machinery. In addition, the coal industry witnessed an almost unprecedented increase in output, as the

possession of cheap and abundant fuel became the foundation of national prosperity.

The early attempts to introduce steam-power into industry were received with some hostility, but the greater output made possible by the use of machinery led to increased prosperity in which all classes shared, and the prejudice against machinery has almost completely disappeared.

The civil and mechanical engineers of the last century placed resources hitherto un dreamed of at the disposal of mankind, with the result that there has been a great improvement in the general conditions of life in those quarters of the globe where their influence has been exerted. These two were joined later by the electrical engineer. The latter introduced an entirely new power medium that is easily generated from inexhaustible natural sources and may be transmitted to distant points in a very simple manner. The full extent of the usefulness of electricity has yet to be realised. Civil and mechanical engineers, too, have by no means reached their zenith, and it is quite certain that engineering generally will in time play an even more important part in life than it does at the present day.



The Story of the Quebec Bridge

THE Quebec Bridge is one of the three greatest examples of the cantilever type of bridge, the other two being the Forth Bridge in Scotland and the Blackwell's Island Bridge, New York. Of these three, the Quebec Bridge is the largest, and the story of its building is a thrilling one.

The dictionary defines the word "cantilever" as meaning a projecting bracket that supports some other object and a simple cantilever bridge is one in which two shore arms support at their extremities a centre span. These shore arms project outward over the river in the form of huge overhanging brackets, and are known as cantilevers—hence the name given to this type of bridge. The name "cantilever" is derived from the French "cant," meaning angle, and "lever," to raise. The cantilever principle is a very old one, having been used hundreds of years ago in China, Japan and India. These early structures were, of course, very primitive, and the type developed very little until comparatively recent years.

An excellent description of the cantilever principle was given by Sir Benjamin Baker at the Royal Institution in the course of a lecture on the Forth Bridge. On this occasion the lecturer exhibited what he described as a living model of the Forth Bridge, arranged as follows:—

"Two men sitting on chairs extended their arms and supported the same by grasping sticks butting against the chairs. This represented the two double cantilevers. The central beam was represented by a short stick slung from the near hands of the two men, and the anchorages of the cantilevers by ropes extending from the other hands of the men to a couple of piles of bricks. When stresses were brought to bear on this system by a load on the central beam, the men's arms and the anchorage ropes came into tension, and the sticks and chair-legs into compression."

The great advantage of the cantilever system is that it permits the cantilever

arms to be built out in pairs on each side of their towers in such a manner as to balance one another during construction, thus rendering external support unnecessary.

In the early cantilever bridges erected in Eastern countries the shore cantilevers consisted of a series of superimposed horizontal wooden beams, each successive beam projecting a little farther over the stream than the one immediately beneath it. When the gap between the two cantilevers had been reduced sufficiently by this means, it was bridged by a central beam, the ends of which rested upon the extremities of the uppermost beams of the cantilevers.

During the past 50 years the cantilever principle has been adopted for bridges constructed of metal and having spans of considerable width. The first true metal cantilever bridge was erected across the Niagara River close to the well-known suspension bridge. This cantilever bridge was opened for traffic in 1883. Two steel piers rising from the stone foundations carried cantilevers having an overall length of 395 ft., and these in turn supported a central or suspension girder 120 ft. in length. The main span, from centre to centre of the piers, was 495 ft.

Some two years later a cantilever metal bridge was constructed across the Fraser River to carry the Canadian Pacific Railway. In this case the clear span measured 315 ft. Subsequently the cantilever principle was adopted for bridges having more than one span, the additional cantilevers being built up on piers having their foundation in the river bed. The most striking example of this type of bridge is the magnificent structure that carries the London and North Eastern Railway across the Firth of Forth. The Forth Bridge has an overall length of 8,296 ft., of which the cantilever portion measures 5,349 ft. and includes three monster double cantilevers and two intervening suspended spans. The total span between the towers of the cantilevers is 1,710 ft. Each cantilever projects 680 ft. and the vertical columns composing their main towers are 361 ft. above high-water level.

Development of Cantilever Type

The suspended spans are each 350 ft. in length.

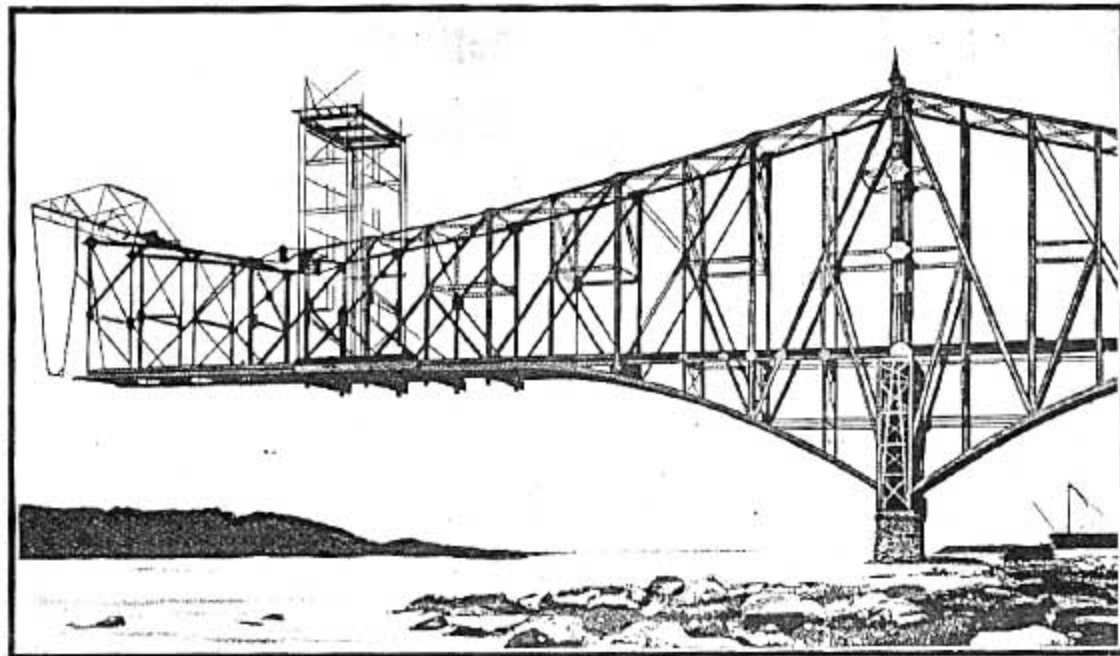
The Blackwell's Island Bridge, New York, is another striking example of the cantilever type. This bridge has a total length of 3,724 ft. and has four cantilevers built up from piers, one on each shore and the other two on the island in the river. The cantilevers are joined together without any intervening suspended spans, and in this respect the bridge differs notably from the Forth Bridge. The five spans of the Blackwell's Island Bridge are all of different lengths, the shortest being 459 ft. and the longest 1,182 ft.

All the foregoing bridges, even that across the Forth are eclipsed by the Quebec Bridge. This bridge was built to enable the provinces eastward of the St. Lawrence River to be linked up with those to the west by means of a great trans-continental railroad. The charter authorising the

construction of the bridge was obtained from the Dominion Parliament in 1882. The newly-completed Forth Bridge was regarded as affording positive proof of the superiority of the cantilever bridge, and it was natural, therefore, that the engineers called into consultation proposed that the St. Lawrence should be spanned by a structure of this type. At the place selected for building the bridge the river is nearly 2,000 ft. in width, 200 ft. in depth, and flows between banks 200 ft. in height.

No definite action was taken until 1887, in which year the Quebec Bridge and Railway Company was incorporated. A design for a cantilever bridge was accepted from a New York engineer who had spent some three years over the work. Tenders were invited and ultimately the contract was awarded in 1899 to the Phoenix Bridge Company. According to the contract the bridge was to cost £2,000,000. It was to have a total length of 3,239 ft., including two anchor arms each 500 ft. in length, two cantilever spans of 562 ft. each, and a central suspended span of 675 ft. Constructed to these dimensions the bridge would have had an overall span from centre to centre of the cantilever towers of 1,800 ft., thus exceeding the span of the Forth Bridge by 90 ft. It was to be provided with a single deck 150 ft. in width, and this was to accommodate a road, two pavements and two tramway and two railway tracks.

In due course work was commenced. Among the first tasks carried out were



Our photograph shows the southern cantilever of the first bridge. The photograph was taken on the 28th August, 1907, immediately before the cantilever collapsed

Fate of First Quebec Bridge

the clearing of the shores for the erection of the approach structures and the preparations for building the two piers in the river. In 1902 the pier nearest the south shore of the river was completed, and then commenced the great work of building up the south cantilever of the bridge. Month by month the mass of steelwork rose higher and higher, and gradually projected farther out over the river. By the summer of 1907 the south anchor arm and about one third of its cantilever span had been erected, the whole extending over the river for some 200 ft.

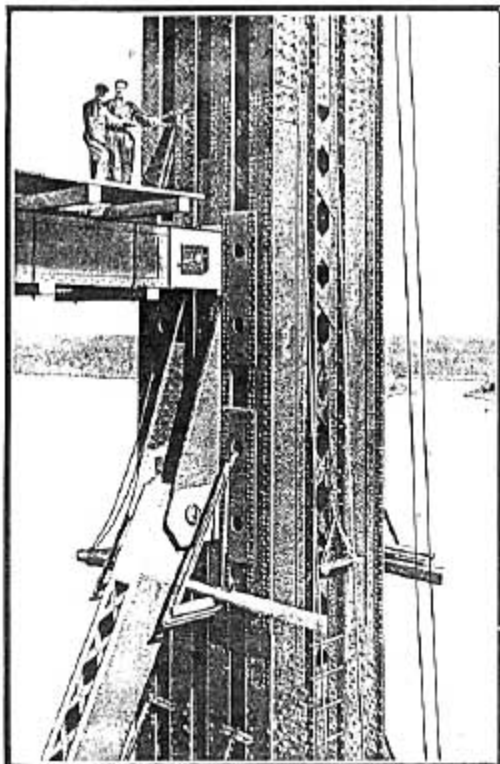
So far all had gone well, but one day an alarming incident occurred. It was noticed that the bottom or compression chords of the anchor arm were bending slightly under the tremendous strain imposed upon them. Word was sent hurriedly to the

consulting engineer, no doubt in anticipation that he would order the immediate withdrawal of all workmen from the bridge until it had been minutely examined. For some unexplained reason no command to cease operations came through, however, and work went on as usual.

On 29th August 1907, came swift and terrible disaster. Shortly before work was due to cease for the day, the compression chords of the south anchor arm suddenly crumpled up. The entire cantilever rocked violently, and with a fearful crash collapsed upon its pier, carrying with it the 86 men who had been at work upon the erection at the time. It was obvious that a large number of these men must have perished, but immediate steps were taken to assist the survivors. In spite of all efforts, however, only 11 men were rescued. Of the 17,000 tons of steel contained in the structure, some 8,000 tons had fallen into the deep channel of the river, while the remainder lay astride the pier and along the bank—a gigantic mass of girders and plates 40 ft. in height, twisted and distorted almost beyond belief. Thus in a few minutes was undone the labour of three years.

This terrible catastrophe cast a gloom over the country and created utter consternation among bridge-building engineers. A searching inquiry into the cause of the disaster was instituted at once by the Government, and a Royal Commission was appointed to examine the wreckage. In due course, the Commission

Proposals for New Structures



Connecting up web members at the centre of the large post over the main pier

the existing piers would have to be moved to a new position. The traffic facilities of the bridge also were reduced and consisted only of two railway tracks and two pavements.

Tenders were then invited from prominent engineering firms, and in order that the best possible design of a cantilever bridge might be secured, the Board allowed competing firms the option of tendering either for a bridge as proposed by the Board or for a structure to the firm's own design. This far-sighted policy met with general approval and no less than 35 tenders were submitted. Ultimately the Board selected a tender put forward by the St. Lawrence Bridge Company, an organisation specially formed for the occasion, and combining the interests and resources of the Canadian Bridge Company and the Dominion Bridge Company.

The design submitted by the St. Lawrence Bridge Company contained several features that aroused considerable interest among civil engineers. This was

submitted their report, in which they expressed the opinion that the accident had been due to errors in the design and building of the bridge, attributable mainly to lack of practical knowledge of how to plan and prepare for a structure on such a huge scale.

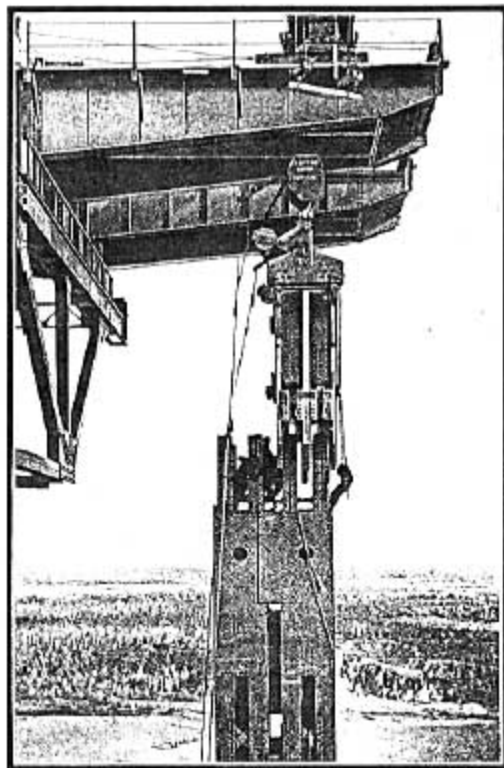
The need for improved means of communication across the St. Lawrence River still remained and was rapidly growing more acute. It was clear that, in spite of the disaster, the bridge must be built, and the Canadian Government took the matter in hand. The shareholders of the Phoenix Bridge Company were compensated for their financial loss, and the Minister of Railways and Canals appointed a Technical Board to design a new cantilever bridge. The plan ultimately put forward by the Board was on a less ambitious scale than that of the Phoenix Bridge Company. It was proposed to build a cantilever bridge 88 ft. in width and having a main central span of 1,758 ft. The reduction of roughly 50 ft. in the length of this span meant that one or both of

particularly the case in regard to the webs forming the steel bracing of the cantilevers and anchor arms, which were fashioned after the letter "K." Several advantages were claimed for this new system of girder bracing, one being that the various K trusses could be assembled without the necessity of first erecting falsework or temporary supporting members. The new idea was not adopted hastily, and it was not until the Board had considered carefully every orthodox system of girder bracing that they decided that the new method was fully as strong and reliable as any of the others, while it compared very favourably in regard to appearance.

The successful design was for a steel cantilever bridge estimated to cost £1,750,000. It was to have an overall length of 3,239 ft., comprising two approach spans 140 ft. and 209 ft. in length respectively, two anchor arms each 515 ft. in length, two cantilever arms each 580 ft. in length and a central span of 640 ft. The traffic limitations indicated in the Board's own plan were observed in the successful design, in which the side walls were shown as 5 ft. in width and the two railway tracks were placed 32½ ft. apart. One condition of the contract was that £250,000 in cash had to be deposited by the company with the Government as a guarantee of good faith, and this was accordingly done.

The task of salvaging as much as possible of the pile of tangled steel girders and plates that represented the former partly-built bridge was commenced by a salvage party of 25 men in December 1909. Charges of dynamite were used to break up the heavy masses of distorted steelwork lying astride the stone pier, and oxy-acetylene torches were employed to cut up the material into portable sections. So well did the men work that in nine months they succeeded in removing about 5,000 tons of scrap material, which was sold in Montreal at approximately £2 10s. 0d. per ton. Of the sum thus realised £8,000 was paid to the salvage party. The portion of the wrecked bridge that had sunk into the channel of the river lay too

Salvaging the Wrecked Bridge



One section of the large link being placed in position at the top of the main pier post

Re-Building Commenced

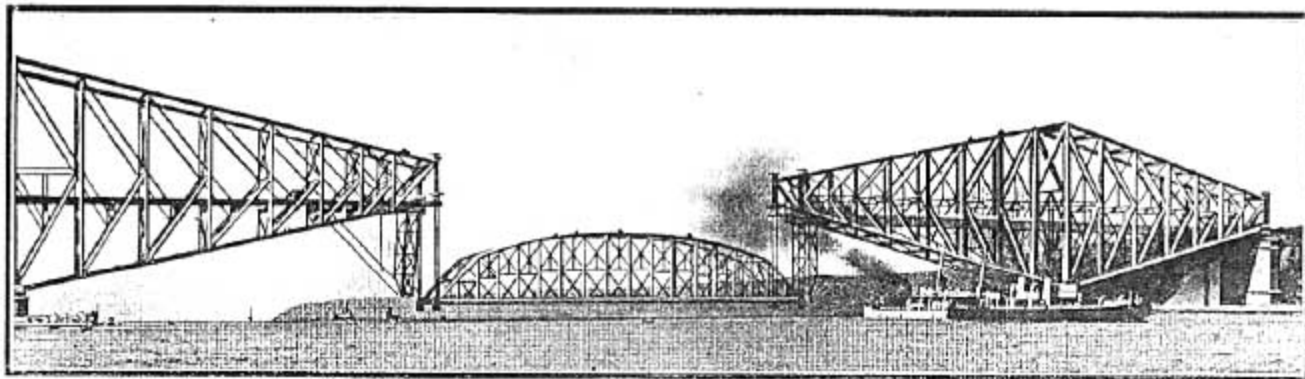
deep to interfere with navigation and therefore no attempt was made to retrieve it.

A contract in respect to the foundations for and the erection of the piers to support the approach ways and cantilevers was placed with a Canadian firm, M. P. & T. T. Davis. The

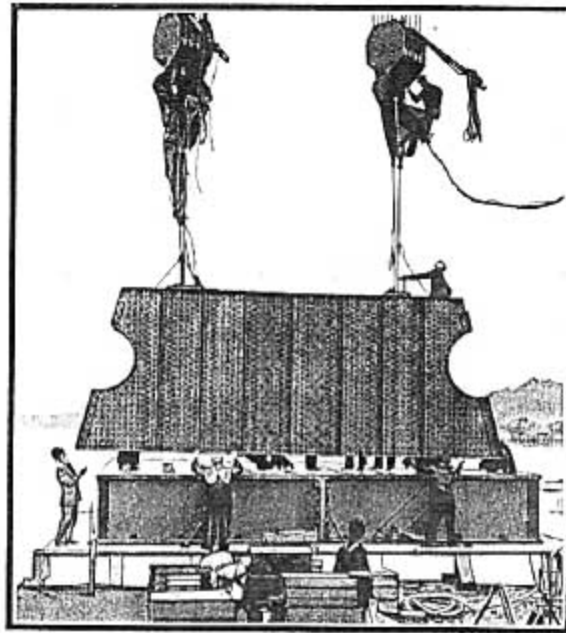
two piers erected in the river by the Phoenix Bridge Company were in good condition—the south one having suffered little from the collapse upon it of the steelwork—but they were too short and unsuitably placed to be of use for the new bridge and were therefore demolished.

The new pier near the south bank of the river could not be established until the wreckage of the former bridge had been removed, but the contractors soon got to work on the construction of the pier for the north cantilever. On the north shore a large wooden building was erected in which to construct the massive caisson for the north pier. When completed this caisson had an overall length of 180 ft., was 55 ft. in width, 68 ft. in height and weighed roughly 1,600 tons. It was successfully launched and then carefully towed to the pier site, where a cavity to receive it had been excavated in the river bed by dredgers.

The caisson affords a means of sinking foundations in the bed of a river, and in principle it may be regarded as a diving bell of enormous size. It is cylindrical in shape, built either of steel or wood, and in appearance is not unlike a gasometer. The cylinder is closed at the top but open at the bottom and the latter has a sharp cutting edge of steel. When the caisson is sunk, the cutting edge beds itself evenly in the river bottom. The lower part of the caisson is rendered airtight by means of a strong partition fitted across it. The men engaged in the task of excavation work inside the chamber



(Above) The suspended span, having been floated down the river and fixed to the hoisting chains of the cantilevers, is being hauled up into position. This photograph was taken at 10.40 a.m. on the 11th September, 1916, just before the span collapsed.
(Below) The workmen are seen placing in position one of the ribs of the main shoe



The Operation of a Caisson

in an air pressure that prevents any water finding its way in below the cutting edge. As the material is excavated it is sent upward through air locks, and the caisson gradually sinks lower and lower as the work proceeds.

The men employed for work in compressed air in caissons are

always specially selected, as the strain is so great that only those of the finest physique are able to withstand it for long. The density of the air produces many curious effects, such as exaggerating noises to an almost alarming extent. Voices also sound harsh and quite different from their normal tones. The worst feature of all, however, is the trouble known as "Caisson Disease." The symptoms of this disease, usually intensely severe pains in the joints, are not felt in the compressed air, but make their appearance when the air pressure is reduced to normal. The mischief is caused by an excessive amount of nitrogen being absorbed by the blood.

If the process of reduction of air pressure is hurried the results are extremely unpleasant, and even dangerous, but if the transition takes place slowly, little inconvenience is felt. Frequently difficulty is experienced in making the workmen stay in the air locks while the pressure is gradually reduced and the excess of nitrogen expelled by means of the lungs. When the necessary precautions are neglected, and a man on reaching the open air is attacked by caisson disease, the only method of giving him relief is to carry him back into one of the air locks and increase the pressure again, subsequently reducing it with extreme slowness.

When salvage operations at the south shore were sufficiently advanced and the north pier had been completed, the equipment used in connection

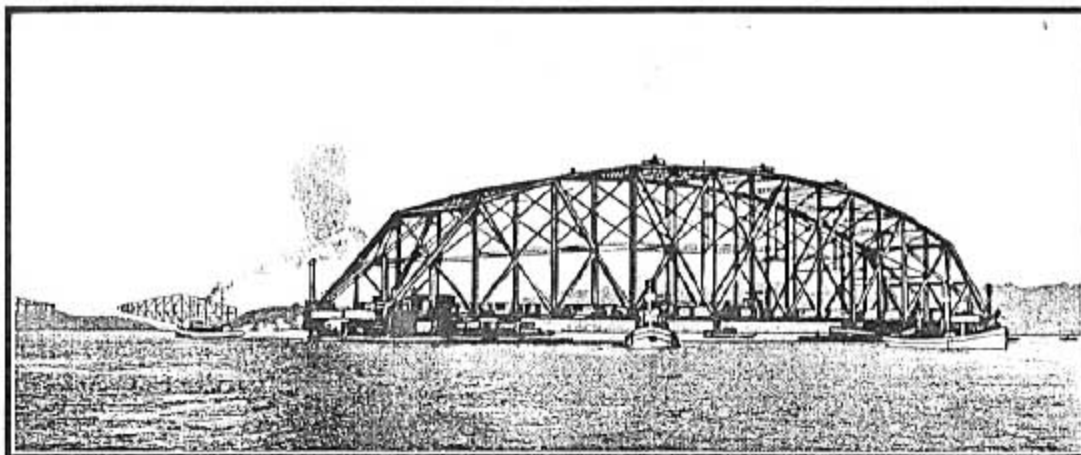
Manufacturing the huge Steel Members

with the latter was dismantled, shipped across the river to the south side, and there re-erected. The caisson built for the south pier was similar to that constructed for the north pier but was somewhat smaller. Some 3,000,000 ft. of timber and 70 tons of bolts were used in constructing the two caissons.

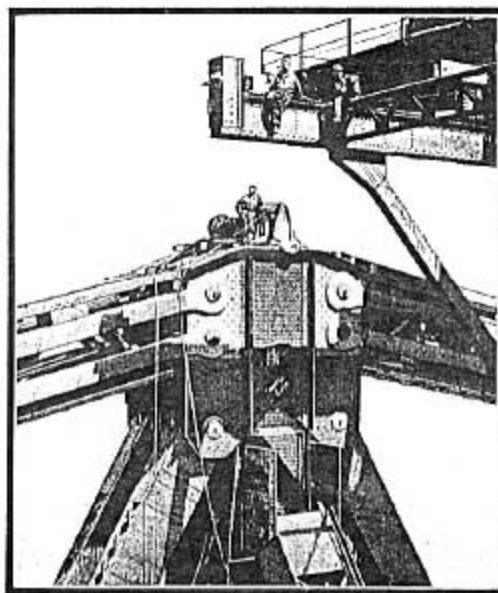
At that time there were no engineering shops in Canada equipped to manufacture such huge steel members as those required for the bridge. Special workshops built of steel and masonry, and thoroughly equipped for the work, were therefore erected at Montreal at a cost of £260,000. In order

to enable the erection of the bridge to be carried forward as speedily as possible during each working season, storage yards 500 ft. in length were laid out on both shores of the river at Quebec. Each yard was equipped with overhead cranes of 83 ft. span and 70 tons lifting capacity, while an elaborate system of railway track was laid down to enable 30-ton locomotive cranes to be used for moving the lighter materials. The utmost care was taken to ensure that the steel members manufactured for the bridge were accurately cast and fitted perfectly one to the other, so that when transported to the site and joined to the existing steelwork, only a small amount of adjustment was required.

Steel scaffolding or falsework, comprising some 8,000 tons of material was built up to aid in the erection of the approach spans and to support the anchor arm trusses during construction. The falsework served also to support the floor system of the anchor arm until this was completed, and to carry the two skeleton towers or erection "travellers," one for each bank. Each traveller measured 210 ft. in height, 37 ft. in length and 54 ft. in width, and was surmounted by two electric travelling cranes, each having a lifting capacity of 60 tons, a transverse travel of approximately 14 ft. and a maximum working spread of 96 ft. To each of the four corner upright girders of the traveller was attached a 90 ft. boom capable of lifting 15 tons, and in addition small 7-ton auxiliary gantry cranes for handling light loads were provided. Each traveller weighed



(Above) The suspended span, floating on the pontoons, being guided up the river. Note in the background the two cantilevers of the bridge ready to receive the span. (Below) One of the large links and connections at the top of the main pier post



Constructing the Cantilever Arms

940 tons and moved along a double set of rails, one set on each side of the runway.

The working season extended from about the end of April until the early part of December, work during the remaining months being at a standstill owing to the river being frozen over.

By the close of the 1913 season the approach arm of the north cantilever was completed, and when operations were resumed in the spring of 1914, work was immediately commenced on building up the K web bracing of the anchor arm and cantilever. Commencing at the shore extremity of the approach arm, the

traveller gradually worked its way towards the cantilever pier, placing in position by means of the 90 ft. booms the necessary falsework, and during the return journey fitting the lower chords of the anchor arm. During the 29 weeks in 1914 in which work on the bridge was possible, 13,636 tons of steelwork were erected and secured in position, an average of 470 tons per week. With the exception of the last two K webs, the north anchor arm was completed. The early part of the 1915 season saw this work finished and the north cantilever span was then built up. When completed, the cantilever projected over the river for a distance of 580 ft. from its pier. At the south side of the river construction was not so far advanced, but by the close of the 1915 season the south anchor arm was completed.

Some idea of the remarkable progress made during that period may be obtained from the fact that 1,823 tons of steel were set in position on the south anchor arm in one week. The record for a single day's work was 670 tons.

Work was recommenced in the spring of 1916 and was carried on so rapidly that the south cantilever arm was completed by the beginning of September of the same year.

While the finishing touches were being put to the steel work on the north portion of the bridge and the south cantilever span was being assembled the huge centre span for linking up the two cantilevers was also rapidly nearing completion. This was being built at

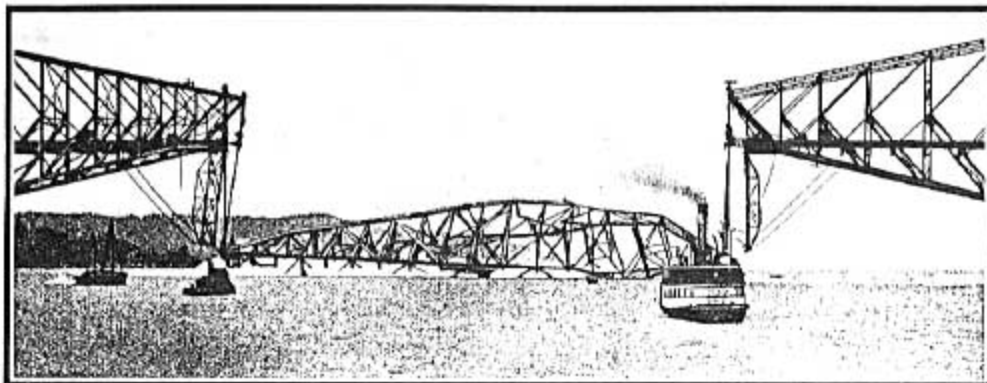
Launch of the Centre Span

Sillery Cove, about $3\frac{1}{2}$ miles downstream from the site of the bridge. The Cove proved very favourable for carrying out this work, as it was protected by shallows and yet at high tide admitted sufficient water to float the pontoons upon which the span was eventually to be loaded. The lattice girder sides of the span were arch-shaped and were 110 ft. in height at the centre.

When word was received at Sillery Cove that the bridge cantilevers were ready to receive the central span, preparations were immediately made for transporting this to the bridge site. The span had been assembled upon the falsework at a height that allowed the pontoons to be floated beneath it and $2\frac{1}{2}$ hours before high tide on 11th September 1916, this was effected, six pontoons being safely manoeuvred into place, three under each end of the span. Each pontoon was constructed of heavy steel framing and steel plate girder bulkheads, and was 165 ft. in length, 32 ft. in width and approximately $11\frac{1}{2}$ ft. in depth.

When the span had been made secure upon the pontoons the whole was floated out into the river and, responding to the tide, moved slowly upstream. Its rate of progress was suitably restrained by five tugs on the downstream side, four of 500 h.p. and one of 1,000 h.p. The $3\frac{1}{2}$ -mile voyage to the bridge site was accomplished without mishap and, after much skilful manoeuvring, in which two reserve tugs that had accompanied the flotilla lent their aid, the span was brought to a standstill directly beneath the gap between the two cantilevers. The ends of the span were then secured by four $1\frac{1}{2}$ in. plough steel ropes, controlled by electric hoists on the bridge deck, to cantilever mooring frames, one of which was hinged from the end of each cantilever and hung vertically. Each mooring frame was capable of holding at its lower end a suspended load of 300,000 lb.

Two 30-ton girders, each fitted on the upper side with two shoes, were placed transversely under the ends of the suspension span, each shoe supporting a corner of the span. At the extremity of each cantilever



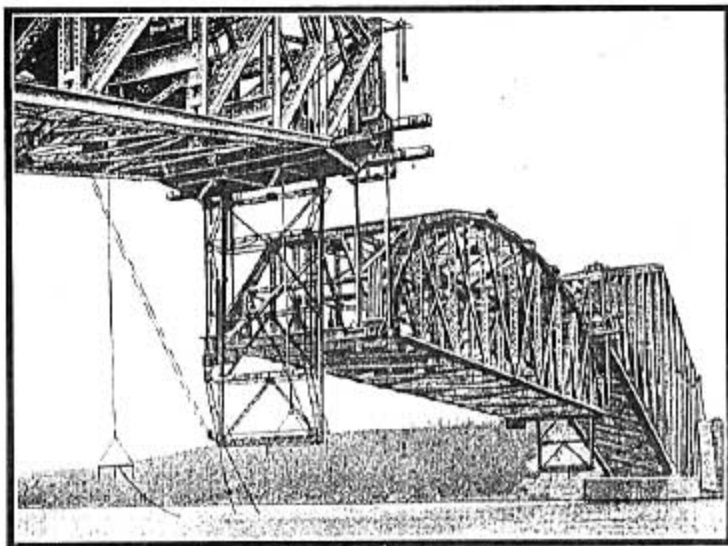
The collapse of the suspended span at 10.50 a.m. on the 11th September, 1916

of 1 ft. diam. holes, 6 ft. apart, for receiving movable pins of the same diameter, by means of which the lengths were linked up.

When the 30-ton transverse girders were safely placed under the floating span, eight hoisting chains were attached, one pair to each end of the two girders, the chains of each pair being 16 ft. apart. These chains extended up through the heavy cross girder—passing on the inner side of the jacks—to the lifting girder, to which they were secured by the insertion of a pin through convenient holes. When the span was safely held by the hoisting chains, the tugs cast off and moved away. The suspended span weighed about 5,100 tons, and the suspension and lifting gear roughly 440 tons, giving a total burden to be lifted of 5,540 tons.

All was now ready for the actual raising of the massive steel structure, and this task was commenced without delay. A power house on each bank of the river supplied compressed air to the hydraulic pumps situated two at the extremity of each cantilever. The pumps in turn actuated the jacks, each of which had a 22 in. diam. ram of 2 ft. stroke, and was capable of working at a pressure of 4,000 lb. per sq. in. As an emergency measure, four hand-operated 1 ft. counterweighted screw jacks were placed at each corner ready for immediate operation.

Immense crowds of people gathered on the banks of the river to witness the



The suspended span shown about half way up, photographed on the 18th September, 1917

Elaborate Hoisting Arrangements

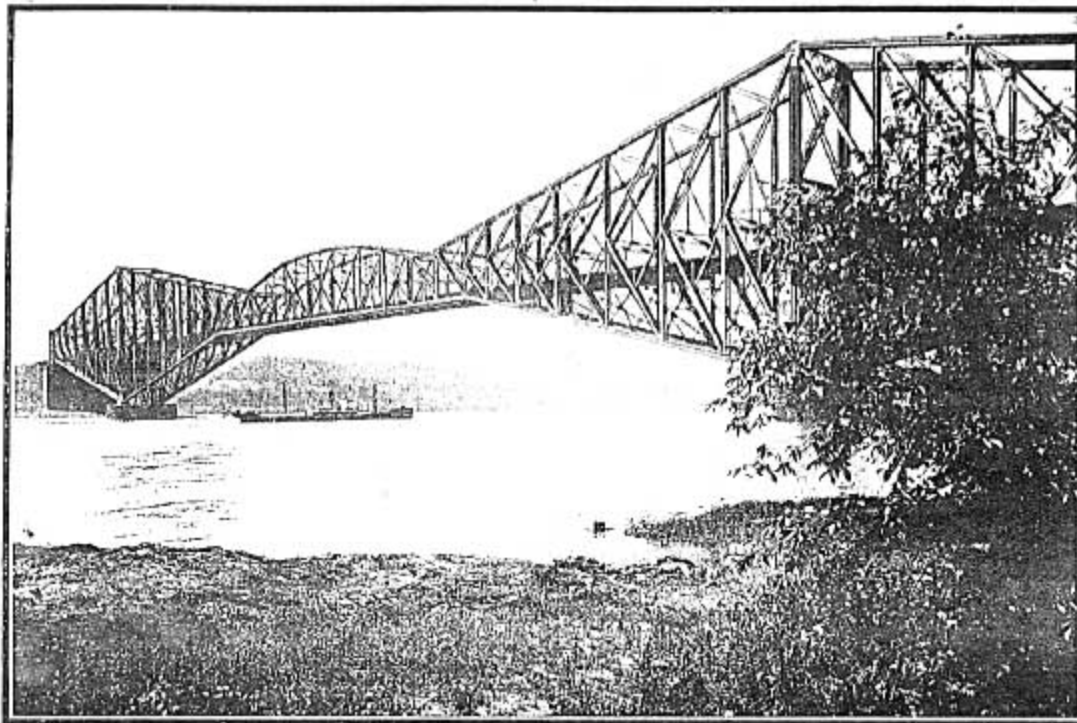
arm an arrangement of rocker bearings supported a heavy transverse girder that served to equalise the load borne by each pair of hoisting chains. Hydraulic jacks were erected on this girder, while a second girder rested across the top of the jack plungers. These top girders, one to each cantilever, were known as lifting girders, and were all provided with holes large enough to admit easily the massive hoisting chains. The latter were of special design, and each consisted of four 28 ft. lengths of solid carbon steel, 28 in. in width and $1\frac{1}{2}$ in. in thickness. Each length of chain had a series

A Second Disaster

hoisting into place of the great span, and a tense silence reigned when the signal was given for lifting operations to commence. As the pumps worked the jacks, the latter slowly raised the girders resting across the top of their plungers. When a lift of 2 ft. was safely accomplished, the pin holes next below those held in contact with the up-raised top girder coincided with the pin holes of the lower girder, and 1 ft. diam. pins were now slipped through these latter holes and the coincident holes in the chains. The chains thus being safely locked in their elevated position, the original, or top pins were withdrawn and the jack rams—and in consequence also the lifting girder—were lowered to their original position, in preparation for the next lift. The cycle of operations was then repeated, each successful lift raising the great steel span a further 2 ft. above the river.

As the span was raised clear of the six pontoons, the latter, released of their load, were slowly carried away by the ebbing tide. Their departure from the immediate scene of operations provided a clear view of the span held in suspension by the chains and ropes, and the crowds of spectators cheered vociferously, while ships' crews added their quota to the applause. When the span had been raised about 30 ft. operations were stopped while the workmen enjoyed a brief but well-earned rest.

After the resumption of operations one lift had been accomplished when the second disaster to the bridge occurred without the slightest warning. Suddenly, at the south end of the span, there was a loud report followed by the sound of ripping metal and, almost before anyone realised what had happened, the great span had partially



The final achievement—the completed bridge, the central span of which is the longest single span in the world

Principal Dimensions of the Quebec Bridge			
Total length of bridge	...	...	3,236 ft.
Length of main span, i.e. from centre to centre of cantilever towers	...	...	1,800 ft.
Length of each anchor arm	...	...	515 ft.
Length of each cantilever span	...	...	580 ft.
Width of suspended span	...	...	640 ft.
Width of bridge from centre to centre of cantilevers	...	...	85 ft.
Clear height of steelwork above high water	...	...	150 ft.
Depth of suspended span at centre	...	...	110 ft.
Depth of cantilevers at main pier	...	...	310 ft.
Depth of main piers below high water	...	...	101 ft.
Weight of steel in bridge	...	...	66,480 tons
Quantity of masonry	...	...	106,000 cu. yds.

Engineers still Undismayed

twisted over and the south-west corner was in contact with the river. It was impossible that, with the tremendous strains now brought into effect, the span could remain in that position and the sinking of the south-west corner was followed almost immediately by the breaking away of successive members of the girder bracing. The weight of the sagging mass of steel soon wrenched the whole span off its supporting transverse girders. With an appalling rumble and splash the structure lurched downward and completely disappeared into the river, bearing with it 90 men who had been engaged upon it in the hoisting operations. Of these men 81, including the chief engineer, were saved.

In face of this disaster it seemed as though the Quebec Bridge was ill-fated, but although the engineers were greatly dismayed by this fresh catastrophe they were not defeated. An official inquiry was speedily held,

but nothing wrong was discovered and the experts finally concluded that the accident had been caused by the failure of the huge steel shoe upon which the span rested at the south end. At the same time no reason could be found for the failure. The cantilevers of the bridge were then subjected to prolonged tests to ascertain whether they had suffered by reason of the tremendous vibrations set up when the attached lifting gear had been so suddenly relieved of its load, and to the great relief of all concerned everything was found to be in order.

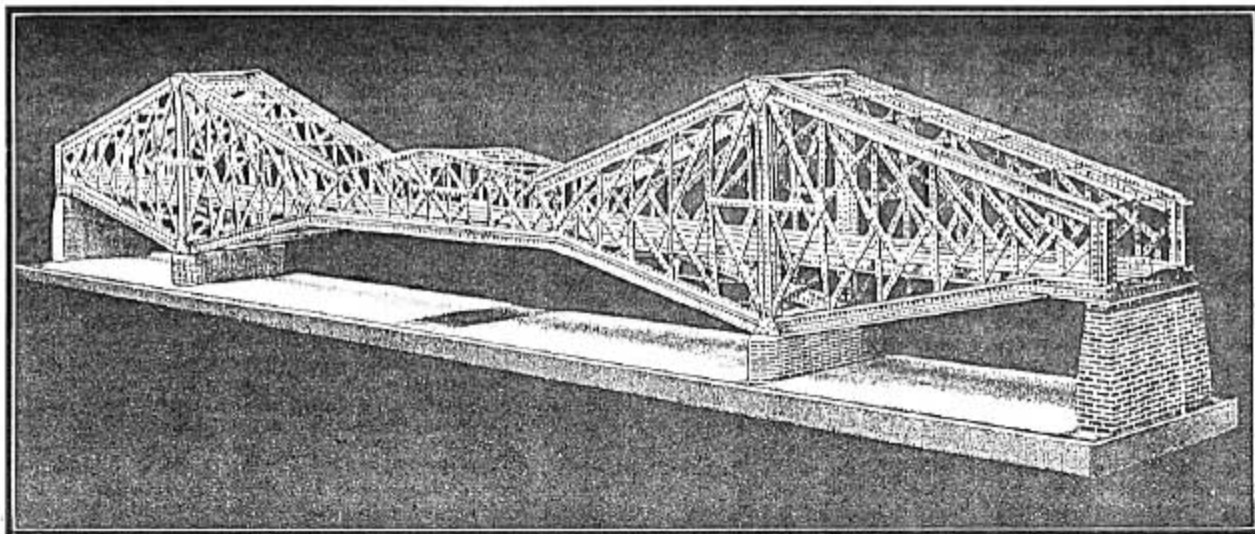
The bridge had to be built, and there was nothing for it but to construct another suspension span to replace the lost one. The falsework that had been erected at Sillery Cove for the assembling

New Span placed in Position

of the first span had afterwards been abandoned, and the task of restoring it to fitness prior to building a new span occupied many months. In the meantime the requisite material for the new span was ordered and obtained. The new central span was completed by August of the following year, and early on the morning of 17th September, 1917, pontoons and tugs conveyed it to the bridge site, where in due course it was safely attached to the mooring frames and hoisting gear.

A few minutes after 9 a.m. the signal to commence lifting the span was given, and once more pumps and jacks commenced their responsible task. Mindful of the catastrophe of the previous year, the engineers and workmen exercised the utmost caution, and no attempt was made to work to a speed schedule. Hoisting was carried out in easy stages, each of 15 min. duration. Twelve lifts, each raising the span a further 2 ft., were made on the first day; 22 lifts, equivalent to a rise of 44 ft., were accomplished during the following day, and 26 lifts on the third day, at the close of which the span was suspended within 30 ft. of its final resting place.

At the time that work ceased on the third day there was a rising wind and indications of a storm, and special precautions were taken to make the span secure. During the night the wind attained a force of 35 miles per hour and it was an anxious body of engineers who inspected the span and hoisting gear on the following morning. Everything was found to be in order, and after assuring themselves that the lifting operations could be safely continued, in spite of the high wind still blowing, the engineers gave the signal for hoisting to be resumed. By 3.10 p.m. the hoisting of the span was



(Above) A fine Meccano model of the Quebec Bridge measuring over 15 ft. in length.

(Below) A striking view looking along the above model, showing the double track for Hornby Trains divided by a steel partition.



Completion of the Bridge

completed and 50 minutes later the connecting pins had all been driven and the span finally secured in place.

During the following three weeks the floor system of the central span was placed in position by travelling cranes and one of the two railway tracks was laid down and riveted. One month after the suspension span was raised into position the first train passed safely over and on 3rd December, 1917, the structure was completed and opened for regular traffic. The

concreting of the side walls for pedestrian traffic and the painting were completed while the bridge was in use.

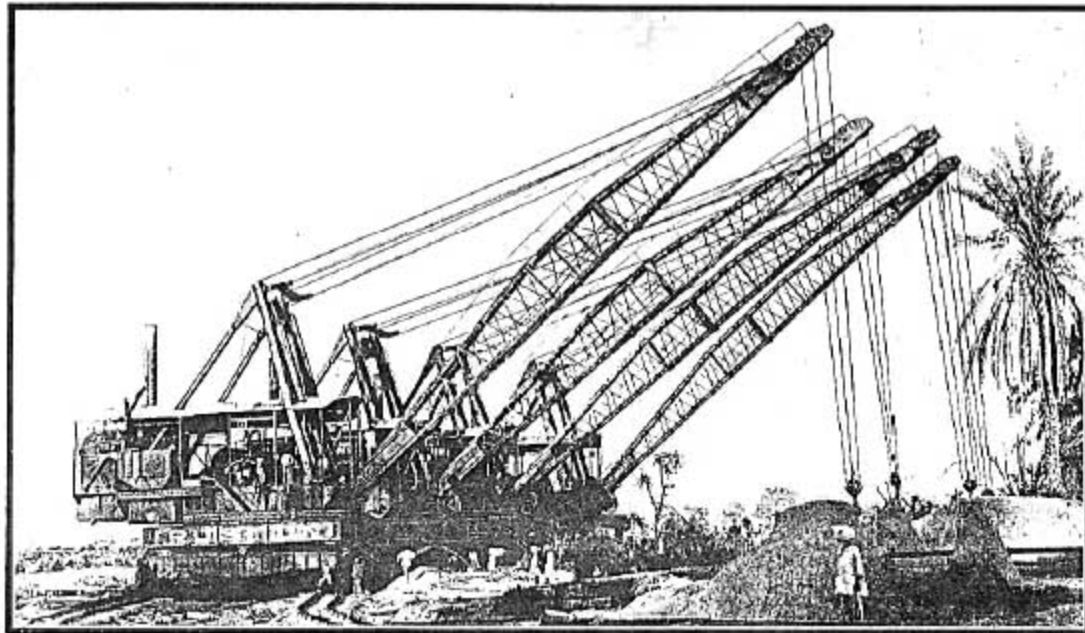
The building of the Quebec Bridge was a remarkable undertaking in many respects. It is probable that never before has an engineering structure on such a huge scale been carried to completion on the site originally assigned to it after two great disasters, in the first of which the crumpling girders dragged to their death 75 men. These two disasters merely strengthened the determination of the engineers that the bridge should be built and, indeed, scarcely had the account of the second disaster been telegraphed throughout the world before it was followed by an announcement that the bridge would be rebuilt and upon the same plan. As we have seen, this third effort proved entirely successful. The building of the bridge from first to last has enormously increased our knowledge of the problems of compression and tension and of the means for dealing with the effects of distortion in trusses.

To-day the Quebec Bridge carries the trans-continental line of the Canadian National Railways over the St. Lawrence River, reducing the distance between Halifax and Winnipeg by 200 miles, and stands as a monument to the ability, courage and tenacity of its engineers.

Digging by Machinery: The Dragline Excavator

A LARGE proportion of the work of Engineers might be described as consisting of digging holes in the ground. This is the case in such undertakings as cutting canals, boring tunnels, quarrying, excavating reservoirs, and sinking the deep foundations of very large buildings. In ancient times big excavation works involved the employment of vast numbers of men because little or no machinery was available and everything had to be done by manual labour, and this state of affairs continued to a considerable extent up to comparatively recent times. To-day, although large numbers of men have to be employed on any big undertaking, the bulk of the work is carried out entirely by mechanical power. The spade wielded by hand is still necessary, but most of the excavation is done by gigantic shovels operated by steam or electric power, and each capable of doing the work of many hundreds of men.

One of the most familiar of digging machines is the Steam Shovel, often referred to as the Steam Navvy. This consists of a huge shovel mounted on the end of a powerful steel arm or jib and operated by a steam engine accommodated in a cab resembling that of a breakdown crane. Steam shovels are employed in the excavation of railway cuttings, open mines and quarries, and canals and docks. They are capable of accomplishing an enormous amount of work, and they are to be found wherever large scale excavation is in progress. At the same time their scope is limited, for they cannot excavate



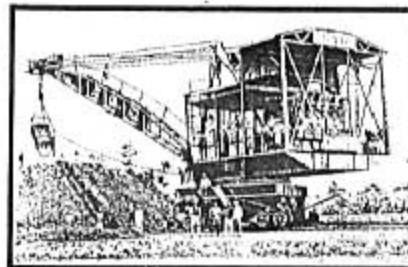
Four of the ten 350-ton Draglines now working on the Canal Scheme at Sukkur, in India.

material below their own level, and they are unfit for use on wet or marshy ground. Where the existing conditions make the steam shovel unsuitable, its place is very frequently taken by another mechanical digger known as the Dragline Excavator, and it is with this machine that we are now concerned.

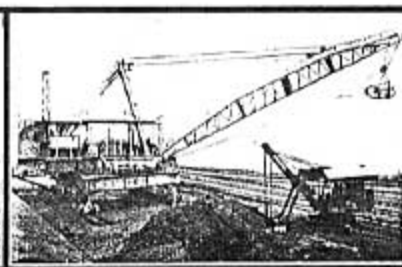
The Dragline gets its name from the fact that its bucket or shovel is dragged towards the machine on a flexible rope instead of being mounted on an arm that pivots on a jib as is the case with the steam shovel. The main difference between the steam shovel and the dragline lies in the method of working. The steam shovel excavates above the level on which it stands, it works away from itself and it advances into the excavation as the work proceeds. The dragline does exactly the

opposite for it excavates below the level on which it stands, works toward itself, and travels backward when it has excavated all material within reach. As regards general construction the two machines are very similar and, as a matter of fact, the steam shovel may be designed in such a manner that it may be converted into a dragline if required by fitting a different jib and a special bucket and adding another winding drum to the machinery.

The dragline has two drums, one for the digging rope and the other for lifting the bucket out of the excavation, regulating the depth of cut and allowing the bucket to swing back after discharging, for another cut. The digging



A rear view of a Dragline showing the Steam Power Plant.



A Dragline and Steam Shovel on Railway work.

How a Dragline Operates

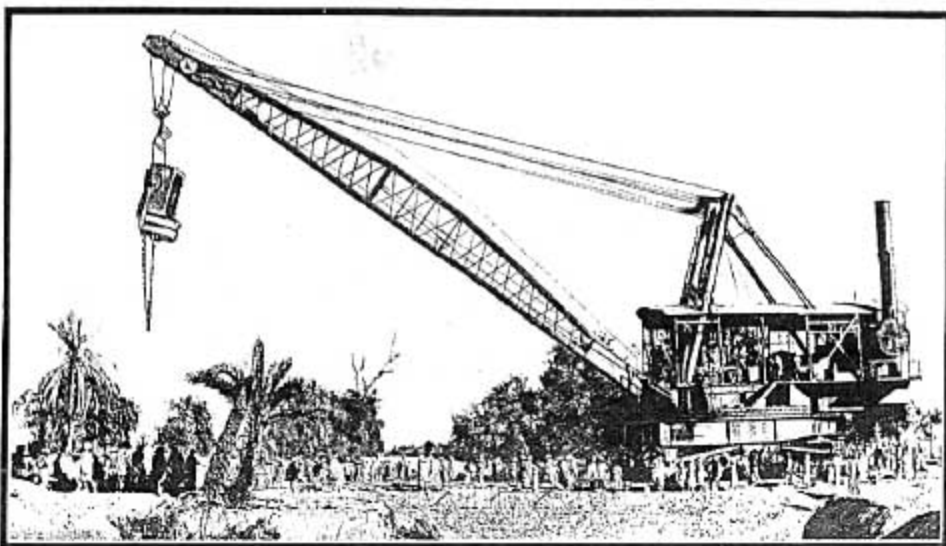
rope passes out of the front of the machine close to the foot of the jib, and is connected to the bucket. The hoisting rope which takes the weight of the bucket and its load runs over the head of the jib and is attached to the bucket.

The jib of a dragline is a lattice-girder and is of lighter design than the jib of the steam shovel. This is made possible by the fact that in a dragline the jib takes only the load due to the lifting rope and this, with the slewing motion, is its only stress. In the steam shovel, however, the jib not only takes the stress from the digging rope, but also bears the whole of the excavating stresses from the bucket arm, with their attendant slewing and digging stresses. In the dragline the stresses at the head of the jib are considerably less than in the case of the steam shovel and so the jib may be made longer. This is an advantage, for it enables the bucket to be thrown out further, and to take a deeper and wider cut.

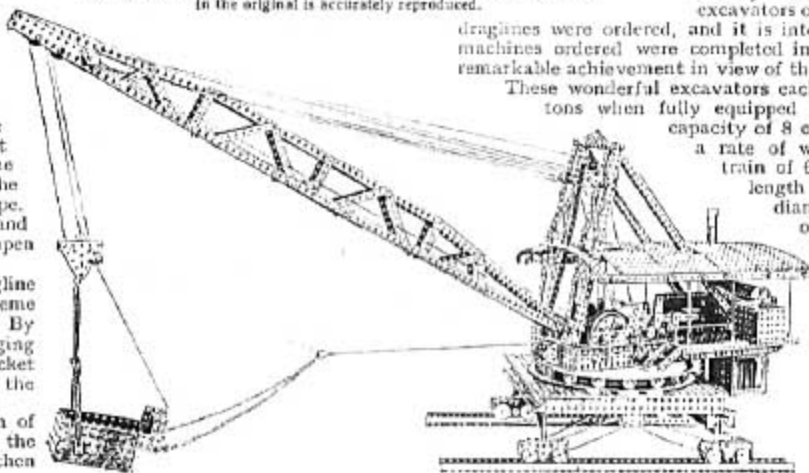
The bucket of a dragline is of simple construction, and, being open at the front and the top, to a certain extent resembles a coal-scuttle. The digging rope is connected to a cross-bar above the front of the bucket, the hoisting rope being fixed to the body of the bucket farthest away from the machine. The bucket is emptied by hauling upon the hoisting rope, and releasing the digging rope. This allows the bucket to tilt forward, and so discharges the contents from the open mouth.

In the cycle of operations of a dragline the bucket is first lowered, at its extreme radius, to the foot of the excavation. By placing the winding-drum in gear, the digging rope is then wound in, hauling the bucket toward the machine, and dragging it into the material to be excavated.

When the bucket is full, the clutch of the digging drum is thrown out, and the hoisting gear is engaged. The bucket is then



(Above) A 350-ton Dragline arouses the curiosity of the natives.
(Below) A fine Meccano model of a Dragline, in which every movement in the original is accurately reproduced.



Ten Tons removed at One Cut

lifted by the hoisting rope, and the digging rope is allowed to run freely, the bucket thus swinging toward the front of the jib. On the machine being slewed over the dumping point, the bucket is discharged in the manner already described.

The largest draglines ever constructed in this country have been built by Ruston & Hornsby Ltd., of Lincoln, for work in connection with the Indian irrigation schemes for the reclamation of millions of acres of barren desert. The work involves the excavation of hundreds of miles of canals and the project as a whole is the largest undertaking of its kind in the world. Some of the channels under construction are over 200 ft. in width and 12 ft. in depth, the excavated material being deposited on the sides to form banks.

In the first place only one

dragline was ordered, but this machine gave such satisfaction that the Indian Government shortly afterward placed an order for a further three excavators of the same type. At a later date six additional machines ordered were completed in seven weeks from receipt of the order, a remarkable achievement in view of their size and complexity.

These wonderful excavators each weigh 250 tons nett and upwards of 300 tons when fully equipped and in working order. The bucket has a capacity of 8 cu. yds. and can excavate 10 tons at one cut, a rate of working that enables the machine to load a train of 60 wagons in an hour. The jib is 120 ft. in length and the drag rope from the bucket $1\frac{1}{2}$ in. in diameter. A cutting power of 30 tons is exerted on the bucket teeth. In spite of its bulk the crane operates very speedily.

The coal bunker is of four tons capacity and is filled by means of a special steam-operated hoist. The main engines are of 400 h.p. and separate engines of about 200 h.p. are fitted for slewing operations. As a crane the machine will lift a load of 22 tons at 125 ft. radius, and although so large and heavy it is very easily controlled by means of steam clutches and steam brakes to all the motions.

For travelling the machine on rails,

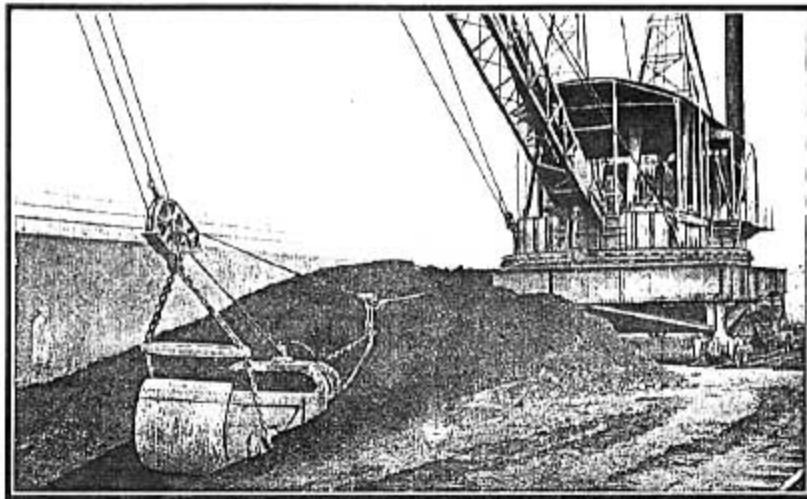
Vast Irrigation Schemes in India

special swivelling bogies are used, all the wheels being driven. In less than one minute the machine digs from seven to eight cubic yards of material and deposits it 200 ft. away from the point where the material was taken out. In other words, the excavator is capable of digging 300 to 400 cu. yds. of material in an hour, and will deposit the material over 120 ft. from the centre of the machine. In order to perform the same amount of work in the same length of time at least 300 men would be required.

In each of these huge draglines there are over 1,000 parts, the heaviest of which weighs over 19 tons. The work of assembling the draglines in India had to be done with inadequate lifting appliances and by native labour under the supervision of the firm's engineers. In these circumstances it is not surprising that considerable difficulties presented themselves. Then there were difficulties of another kind. For instance, one of the engineers in charge dislocated his shoulder, but carried on for a considerable time until help arrived, while another engineer nearly lost his life through being bitten by a snake while oiling the machinery. The engineers had also to contend with stifling desert heat, bad water supply and fever. Notwithstanding all these difficulties, however, four of the excavators were erected in three months, a very creditable performance in the circumstances. Even when the machines were finally erected the difficulties were not over, for the natives had to be educated to drive and operate them. It is interesting to note that the draglines are fitted with searchlights to enable work to proceed at night.

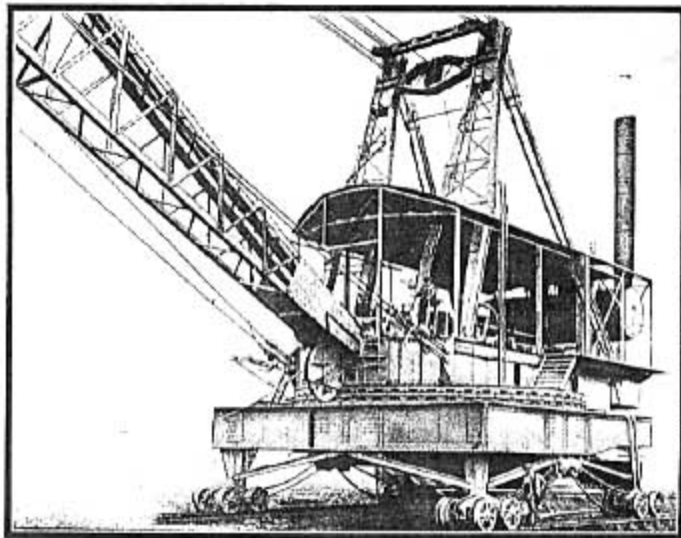
It was on the Sutlej Valley irrigation scheme that the original dragline was first employed in India. The machine began work in April 1924 and on the average excavated 670,000 cu. ft. per day. Some idea of the economy effected in labour may be realised from the fact that this amount of excavation represents the work of 8,000 coolies, who would not only have had to be paid, but fed and housed as well. When completed the Sutlej Valley scheme will irrigate 8,000 square miles, or 5,000,000 acres, of desert. The cost of the work is estimated to be over £7,750,000.

Another scheme at Sarda, in the United Provinces, includes the construction of a great



(Above) How a Dragline digs its way into the Earth.

(Below) A near view of the immense Carriage upon which the Dragline travels.



The World's Greatest Barrage

canal system for irrigation purposes. The work consists of the excavation of 478 miles of canals and branch canals, and no less than 3,370 miles of distributing channels. When complete the scheme will provide for the irrigation of 1,368,000 acres of what is now waste land. It is estimated that the total cost will be over £5,600,000. This scheme affords a good example of work for which the steam shovel would be unsuitable.

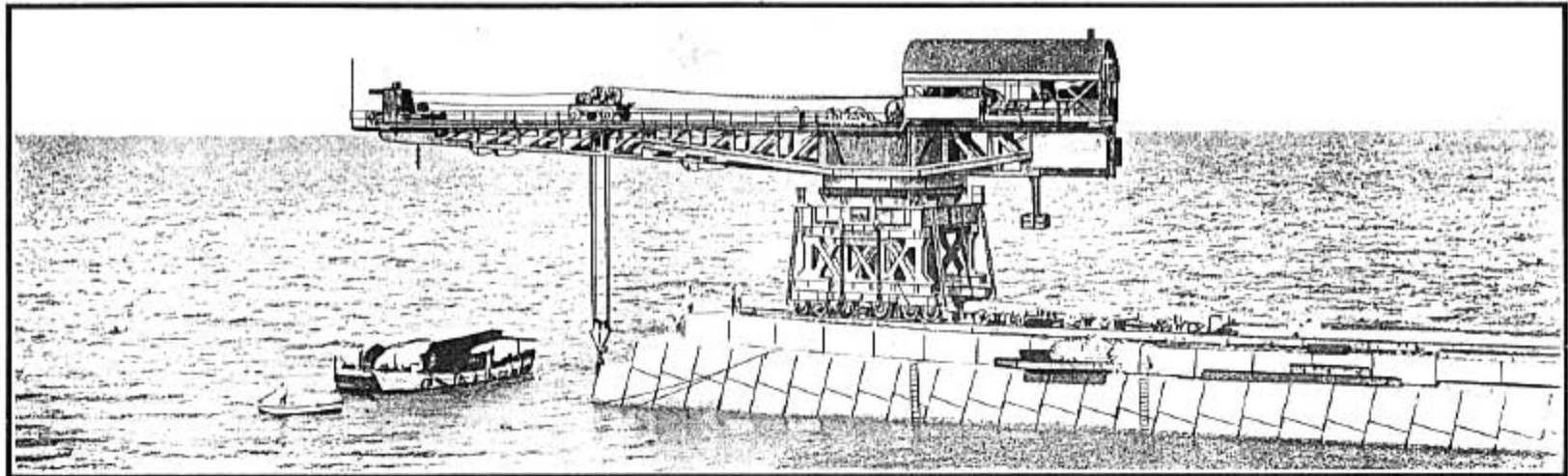
Draglines are also being employed in the canals scheme at Sukkur, situated in the province of Sind. In this area the excavators are being used in the construction of 50,000 miles of canals, three of which are to be larger than the Suez Canal. The completed scheme will give control of cultivation of over 7,500,000 acres, of which nearly 6,000,000 acres will be reclaimed sandy desert area, brought into cultivation for the first time. The area made arable will be larger than the whole of the cultivated area of Egypt, and it is estimated that when complete this scheme alone will cause a total annual increase in the wealth of the country by nearly £19,000,000.

Included in the Sukkur scheme is the building of the Lloyd Barrage, a massive masonry dam across the River Indus to control the fluctuations of the river. This will be the greatest work of its kind in the world eclipsing even the wonderful Assouan and Sennar dams in Egypt. It will be nearly a mile in length and over it will be constructed a bridge of 56 spans each 60 ft. in length and each fitted with a massive water-gate 18½ ft. in depth and weighing 50 tons. The top girders of this bridge will be 770 ft. above the foundations.

Work on the Sukkur scheme commenced in October 1923, and although 20,000 men are employed, it is such a huge project that it is not expected that the contract will be completed before the summer of 1930 at the earliest. The total cost will be over £13,000,000, the Lloyd Barrage alone costing £4,500,000 and the canals £9,000,000.

In certain circumstances it is not practicable to utilise steam power. This is the case in connection with excavation work in progress at Metur, presidency of Madras, India. In this district water is scarce and unsuitable for steam boilers and the draglines employed are each driven by their own oil-electric plant.

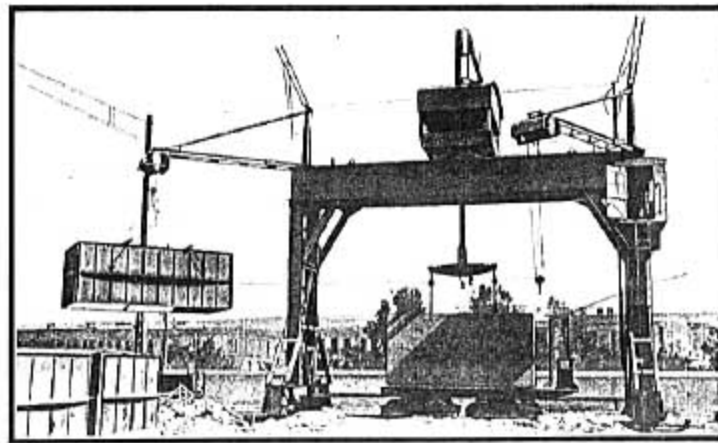
How the Engineer Holds Back the Sea



(Above) A fine example of a giant Block-setting Crane engaged in building a breakwater in connection with the harbour extension at Madras.
 (Below) A photograph of a Gantry Crane lifting a block of concrete from a railway truck preparatory to carrying it down to the harbour.

THE mastery of the Earth that the engineer is acquiring is nowhere shown more emphatically than in the construction of sea-walls and of great harbours in which ships may find shelter from storms and land their cargoes without disturbance. Other engineering achievements such as bridges, tunnels and canals are no doubt impressive, but when the initial difficulties of their construction have been overcome, their maintenance is a comparatively easy matter, whereas sea-walls are subject to continuous hammering from the waves and depend for their continued usefulness on constant observation and repair.

On this account harbour engineering possesses a fascination of its own and the reasons that make sea-walls necessary, and the remarkable methods of under-water construction adopted in building them, are of the greatest interest. The great expansion in shipping, due to the introduction of steam power last century, is mainly responsible



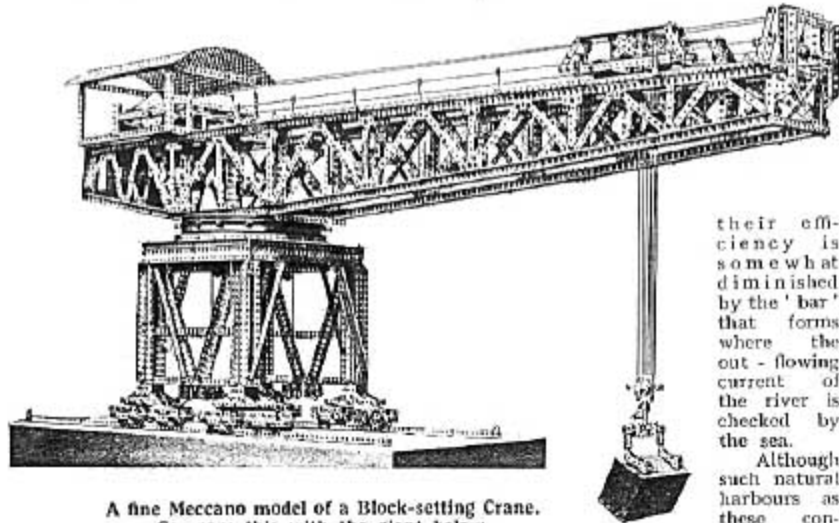
for the present-day importance of this branch of engineering, but harbour works became a necessity much earlier in maritime countries such as Great Britain, in spite of the existence of natural harbours. It is on the methods adopted to protect the frail wooden vessels of Tudor times from the fury of the waves that the engineers of to-day have founded their plans.

It is a curious fact that almost every country with a sea coast seems to have at least one natural harbour, and in many cases these are sufficiently large to accommodate large fleets of ships. One of the largest of these natural harbours is the Bay of Rio de Janeiro in South America, which runs in a northerly direction for 15 miles with a width varying from two to seven miles. Surrounded by high mountains, with an entrance less than a mile in width, it is protected on each side by bold headlands.

In Great Britain, Milford Haven in Wales, stretching inland for some 10 miles,

Defects of Natural Harbours

is unequalled as a sheltered harbour. Other natural harbours are formed by the mouths of rivers, such as the Thames, Mersey, Humber, Forth, and the Seine, but



A fine Meccano model of a Block-setting Crane. Compare this with the giant below.

their efficiency is somewhat diminished by the 'bar' that forms where the out-flowing current of the river is checked by the sea.

Although such natural harbours as these continue to be useful, they

are not all favourably situated. Milford Haven, for instance, is of little importance from a naval point of view, and is too far away from centres of trade and manufacture for use as a commercial harbour. The requirements of modern times have therefore made it necessary to augment the number of harbours, either by improving some natural feature—such as a bay or an inlet—or by constructing more elaborate works and enclosing large areas of the sea by harbour walls or breakwaters.

The branch of engineering under consideration is not concerned with harbour construction only, for sea-walls are very necessary for other purposes, apart altogether from the fact that they often make delightful promenades from which we may enjoy the sea air or cast our fishing lines when on holiday! The constant hammering of the waves upon undersea cliffs, for instance, so that the sea encroaches upon the land and the coast-line becomes completely altered. The construction of protective sea-walls is practically the only method of preventing the evil effects of such encroachment.

Without the aid of mechanical appliances most of the great sea works of the present day would be practically impossible of construction. Foremost among such appliances are cranes of various types and of these the most impressive and at the same time most

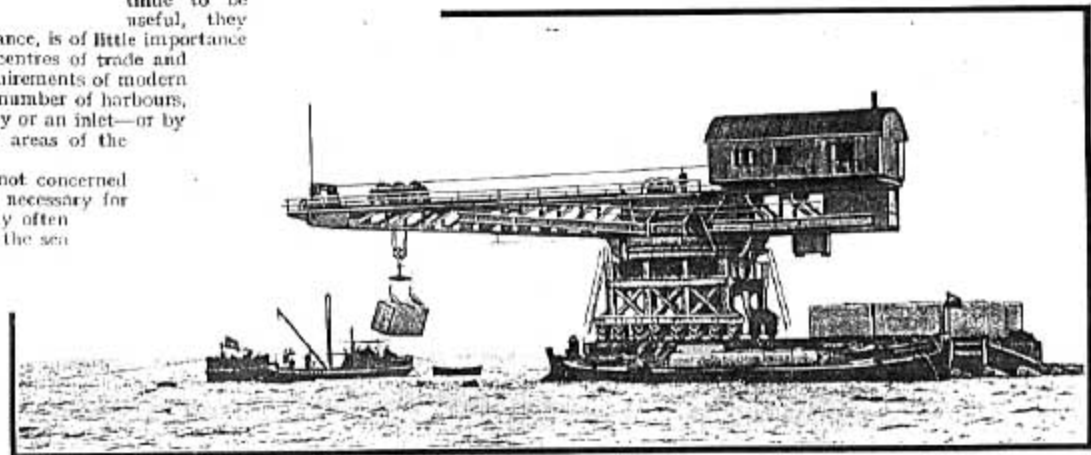
Development of Breakwaters

interesting are the giant block-setting cranes that handle huge blocks as though they weighed pounds instead of tons.

In order to understand the particular work in which these block-setting cranes are employed, we must look a little further into the methods of harbour construction. In the first place, no two breakwaters or harbours are exactly alike, and almost every harbour requires particular treatment.

In some cases a mound of rubble or stone, deposited in a scattered manner and standing above high-water mark, will serve the purpose, as is the case with the breakwater at Algiers, where a rubble mound is protected by 25-ton blocks heaped on the sea bed. In others currents or storms would soon move such scattered material and break it down. More elaborate methods are then necessary, such as the 'sack-block' system. This employs barges with trap doors. The interior of the barges is lined with sacking and in this concrete is deposited. The sides of the sacking are then brought together and laced over the top, and the barges are towed out to the site of the breakwater. The trap doors are then opened and the concrete drops into the sea, where it is solidified by the action of the water and soon becomes a perfectly hard mass. The sack-block method was used in the construction of the underwater portion of the breakwaters at Newhaven and La Guaira, where layers of blocks weighing 100 tons were successfully laid, each extending across the whole width of the breakwater.

When a natural bay is sufficiently sheltered by a projecting headland, it is only necessary to throw a breakwater across the inlet in order to convert it into a harbour. In such a case the entrance would be between the ends of the breakwater and the headland, if the depth of the water there is suitable. Such harbours as these are found at Plymouth and Cherbourg. Sometimes a single breakwater, thrown from a projecting point of a bay and enclosing a partly sheltered area of water, is sufficient protection, as at Holyhead, Alexandria and Table Bay. Where no headland or sheltered bay exists in a place where a harbour is required, it becomes necessary to form an entirely artificial harbour, which is, of course, a more extensive project.



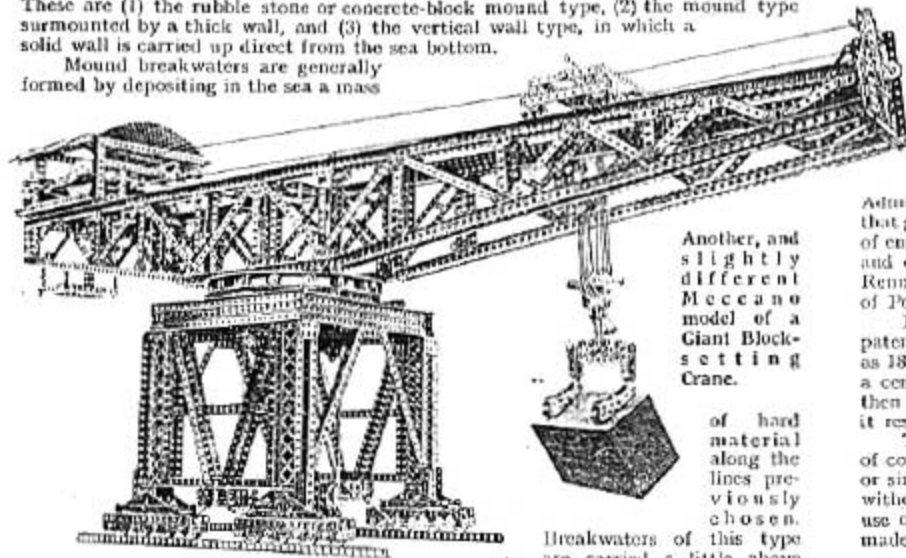
Lowering a block into position at the end of a breakwater.

Harbour Works at Table Bay

Such harbours as these are found at Kingston, Madras and, nearer home, at Dover.

Although breakwaters thus differ in detail in almost every case, they may be broadly divided into three classes according to the method of construction used. These are (1) the rubble stone or concrete-block mound type, (2) the mound type surmounted by a thick wall, and (3) the vertical wall type, in which a solid wall is carried up direct from the sea bottom.

Mound breakwaters are generally formed by depositing in the sea a mass



Another, and slightly different Meccano model of a Giant Block-setting Crane.

of hard material along the lines previously chosen.

Breakwaters of this type are carried a little above

high-water level and are placed as squarely as possible to the direction of the heaviest waves, for if placed obliquely the material would soon be scattered. Such breakwaters are generally adopted when an abundant supply of suitable material is close at hand. They are only constructed, however, when the space on the sea-floor that the breakwater will occupy is of no consequence, and where no quay is required to be built.

The mound type of breakwater is well represented by the works at Table Bay and Alexandria. The former breakwater runs in a north-easterly direction from a point to the north of Cape Town, and gives shelter from the north-west where Table Bay opens on to the Atlantic Ocean. It consists of a mound of rubble stone, which the sea has now levelled on the ocean side to a gradient of about 1 in 9 for some distance below low water. The original structure, which was begun in 1860, was 2,400 ft. in length. In 1881 an extension was added, bringing the total length of the breakwater to 3,760 ft. The earlier breakwater was in a depth of 30 ft. but the later works extended it into water 50 ft. in depth.

Although this type of breakwater illustrates the simplest possible construction, it requires a large expenditure of material. At Table Bay this material was at hand in the form of stone excavated from a neighbouring site, so that the consideration of transport of the material did not arise.

In the second type of breakwater a rubble mound—similar in many respects to the mound used in the first type—is surmounted by a massive wall. This type is well represented by the Colombo breakwater. The advantages of the mound

Invention of Portland Cement

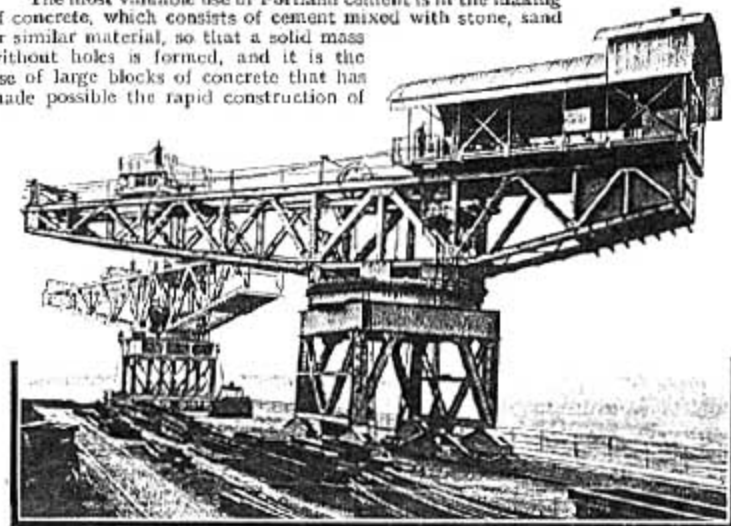
and wall type are that it requires less material than the mound type and also that the top of the wall may be used as a quay in fine weather. Sometimes this type of breakwater is modified and additional protection afforded by laying large concrete blocks at random on the seaward side, as is the case with the breakwater at Boulogne Harbour, commenced in 1879.

In the third type of breakwater a massive wall is built of blocks of stone, dove-tailed one into the other in order to present the maximum resistance to the waves. Although this type requires less material than either of the others, it necessitates more careful construction and also involves the employment of divers. It is dependent, too, on the existence of a hard sea-floor at the place where it is to be erected, and the depth of the water must not be too great.

By far the most notable example of this type of breakwater is the Admiralty Harbour at Dover. The construction of the massive breakwaters of that great harbour represents the most modern achievement in this particular branch of engineering. From time to time considerable sums had been spent on improving and extending works erected by such distinguished engineers as Perry, Smeaton, Rennie and Telford, but no satisfactory results were obtained until the invention of Portland cement, which revolutionised this branch of engineering.

Portland cement was invented by Joseph Aspdin, a Leeds bricklayer, and patented in 1824, although the secret is believed to have been known to him as early as 1811. Aspdin found that by mixing limestone with clay he was able to produce a cement that possessed considerable advantages over any other similar material then known. The material derived its name from the fact that when it sets hard it resembles closely the building stone quarried at Portland.

The most valuable use of Portland cement is in the making of concrete, which consists of cement mixed with stone, sand or similar material, so that a solid mass without holes is formed, and it is the use of large blocks of concrete that has made possible the rapid construction of



Two huge cranes at work on a South African Harbour.

The Admiralty Harbour, Dover

modern harbour works of enormous strength and extent.

The first part of the modern harbour works at Dover was completed in 1871 at a cost of £680,000, and consisted of a breakwater 2,100 ft. in length, extending to a depth of about 48 ft. at low water. For some years this breakwater served the purpose required, but the continued increase in the amount of shipping and the additional requirements for strategical purposes, rendered further work necessary.

Between 1898 and 1909 an additional scheme was carried out and two other breakwaters were built, enclosing a large area of anchorage, now known as the Admiralty Harbour, the construction of which was a great engineering feat. We are better able to gain some idea of the magnitude of the task that confronted the engineers when we learn that the total length of the breakwater is over two miles. The finished harbour is over 610 acres in extent and is sufficiently extensive to shelter a whole fleet. The work included the extension of the former breakwater by 2,000 ft., the reclaiming and excavation of a large portion of the chalk cliffs immediately behind the harbour, the building of a new breakwater at the South end, and a new breakwater, 3,850 ft. in length, at the East end.

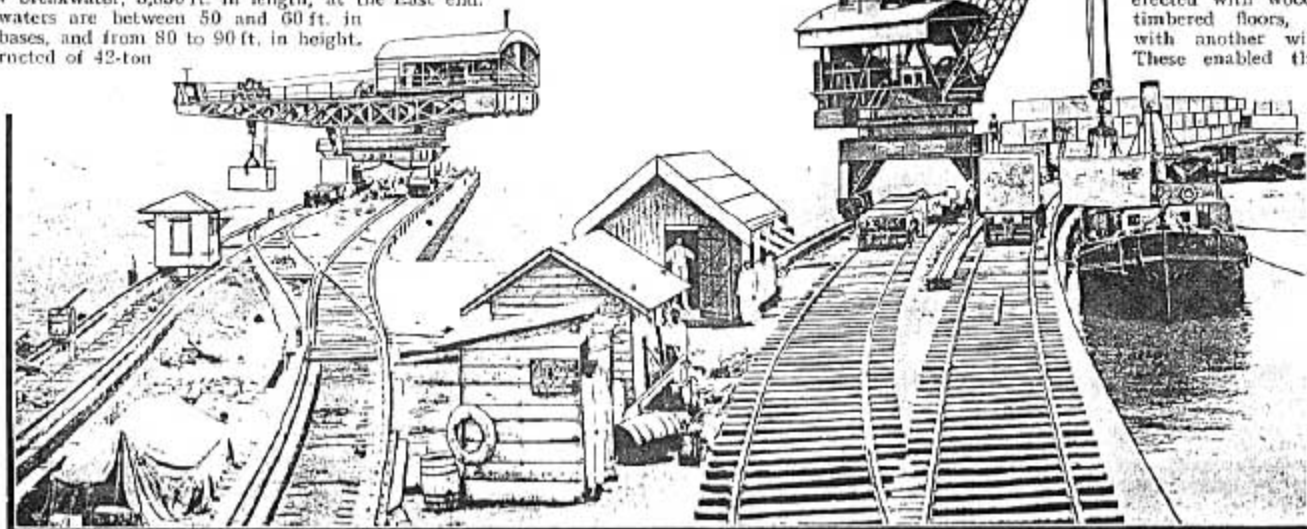
The breakwaters are between 50 and 60 ft. in width at their bases, and from 80 to 90 ft. in height.

They are constructed of 42-ton

concrete blocks, which were formed in special block-making yards erected under the shelter of the cliff. These blocks measure 14 ft. by 7 ft. by 6 ft., and consist of a mixture of gravel, sand and cement. This was poured into wooden moulds in liquid form and, when the mixture had set—for which a week was generally required—the

sides of the mould were removed and the blocks were ready for transport to the point at which the work was proceeding. For transporting these blocks along the quay huge Goliath cranes were employed. This type of crane, under the name of Travelling Gantry crane, is familiar to all our readers from the excellent Meccano models of it that can be built.

The cranes ran on a track supported on a special platform which, in view of the fact that the cranes weighed 100 tons unloaded, was very substantially supported. In the first place, ironshod piles, 100 ft. in length and 20 in. square, were driven



An interesting photograph showing two types of Block-setting Cranes. On the left the Titan using friction grip for lowering the block, and on the right a Jib Crane specially constructed for harbour work, using Fidler's gear.

into the sea floor in groups of six on each side of the line on which the breakwater was to be built. Each group was separated by a distance of 50 ft. and between the two lines of piles was a clear 70 ft. In all, the scheme required half-a-million cubic feet of timber, which was specially selected by an expert sent over to Tasmania for the purpose.

When the massive piles had been satisfactorily driven home into the sea floor by the heavy blows of the powerful pile from one row to the other. It was sufficient strength to withstand the would necessarily be exposed accordingly these were then laterally by lattice girders. laid down upon which cranes were to

drivers, cross-girders were placed necessary to give the structure violence of the storms to which it before the work was completed, and braced diagonally by strong ties and Finally the heavy timber flooring was the two 100 ft. tracks for the Goliath be carried. In effect, therefore, two solid piers had been erected with wooden supports and timbered floors, and braced one with another with cross girders. These enabled the gantry cranes to travel out to the end of the piers and to drop concrete blocks at any desired point between the shore and the pier ends. As the blocks were laid the cranes advanced and so laid succeeding tiers, each tier being built up to the level of the finished breakwater before the next was proceeded with.

The blocks were dovetailed one into the other on all sides, in order to give the breakwater solidity to resist the fury of the waves. They were not dovetailed in the manner used in the building of a lighthouse, but instead were keyed together by cutting semi-circular grooves in their faces, it being arranged that these grooves came opposite to each other in pairs. When the blocks were in position, bags of concrete were placed in these grooves. The action of the water at once caused the concrete to solidify, so that each block had really two concrete pillars holding it in position.

In building a breakwater the engineers are very largely at the mercy of the

Three Million Tons of Masonry

weather, for naturally no work can be done when the seas are running high. On the other hand, when the water is calm work continues whenever possible during both night and day. At Dover, even on the best days, it was only possible to work three hours on each tide owing to the strong currents. Notwithstanding this, in one particular month over 600 blocks were laid, showing a progress of over 75 ft. One of the points that had to be carefully watched was the organisation of the block-making yards. In bad weather they had to be kept free from congestion by unused blocks, and in good weather, when the work on the breakwater was being pushed forward with all possible speed, it was necessary to ensure that they were sufficiently well staffed to be able to cope with the increased demands made upon them so as not to delay the work.

In the construction of the first pier at Dover (completed in 1871) only 91 ft. was built during the first 12 months, but in the new Admiralty Harbour 400 ft. of work was constructed in the same period, showing how great was the advance in harbour engineering. In the new harbour over 1,920,000 tons of masonry were used, and as the blocks averaged about 30 tons in weight, the total number required was about 64,000.

The harbour works included the excavation of a portion of the cliff and it became necessary to build a retaining wall to protect the exposed chalk. This necessitated over 1,000,000 tons of blocks and masonry, in addition to that required by the breakwaters themselves.

Besides the East breakwater and the Admiralty Harbour extension, another breakwater had to be constructed to complete the scheme. This is quite separate from the two former, and is known as the Island breakwater. In order to save time the engineers decided to build it at the same time as the other breakwaters.

To this end they set to work to erect a huge steel frame in the sea at the end nearest to the East breakwater, but before the frame was complete a great storm entirely destroyed it. Six months were required to remove the wreckage, so that instead of gaining time, time was actually lost.

After this disaster the steel frame idea was abandoned. In its place the trackway used in the construction of the East breakwater was carried on temporary supports across the south-east entrance to the harbour to the Island breakwater. This enabled Goliaths to bring up the blocks for the Island breakwater from the

Base for the Dover Patrol

block-setting yards, and at the same time allowed the cranes to be withdrawn in bad weather.

In the Dover Harbour we have an excellent example of how, for the time being, man has won a victory over the sea.

The great breakwaters have withstood winters of furious storms and the huge waves have not damaged them in any way. The harbour was of incalculable value to the Allies during the War, not only as a port from which troops and munitions might be embarked to France, but also as a base for the Dover Patrol. Here, too, warships, torpedo boats and other craft that were concerned in protecting the cross-Channel traffic from attack by enemy warships, found refuge.

Before leaving the subject of Goliath cranes, which were specially used in the building of Dover Harbour, we must mention that in addition to placing the huge concrete blocks in position these cranes were employed to operate huge clam-shell grabs used for clearing the sea-floor. These grabs were capable of bringing up five tons of material at a time. In many places the ground was too hard for the grabs to get a bite, and then a solid block of iron with three projecting teeth was used. These

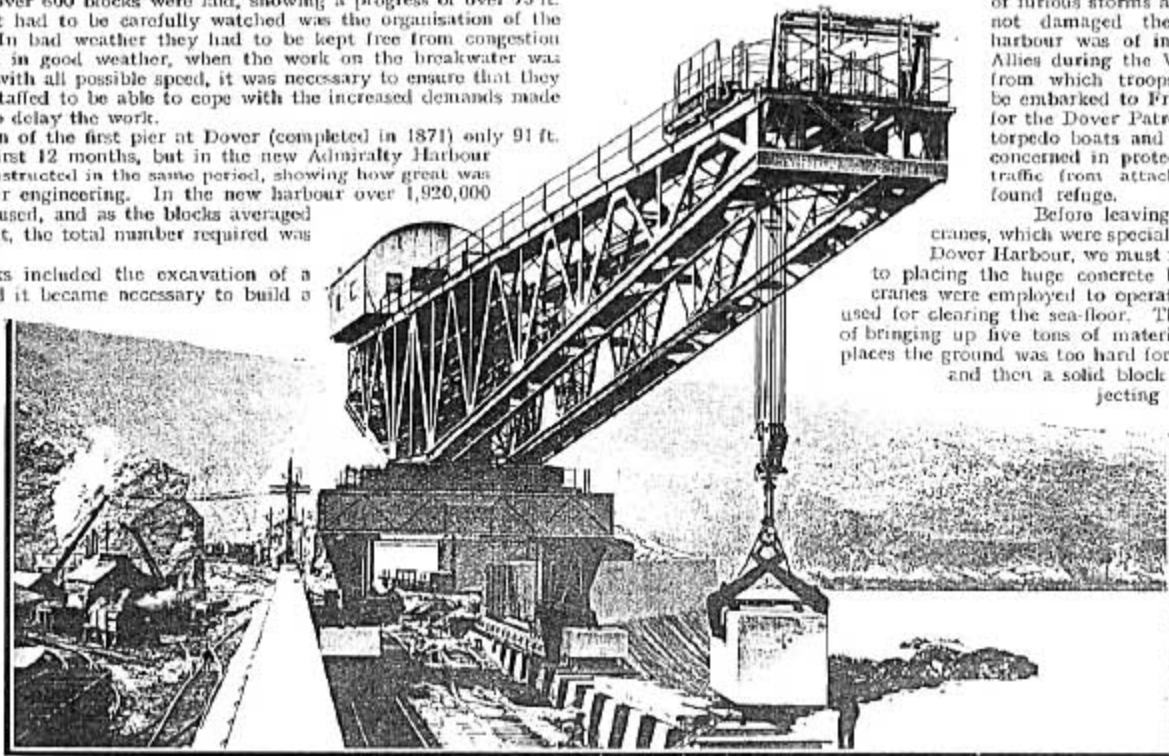
"breakers," as they are called, were also operated from the Goliath cranes. On being lowered at speed they crashed to the sea-floor, splintering the chalk into large pieces that were gathered by the grab.

The Goliaths were also employed to lower the diving-bells from which the divers set the blocks, telephoning to the crane-man the exact direction so that he could move the crane as required

and so set the block in the desired position.

Another and larger type of crane used in connection with harbour construction work is that known as the "Titan." This crane has a jib of the cantilever type and the lead trolley runs along its upper boom, the whole jib turning on a live ring in a similar manner to that of the large jib cranes. Usually the Titan crane is steam operated, although cranes have been made for use with electric power where current is available.

Titan cranes are frequently constructed of such a size that they weigh 500



A striking specimen of a Titan Crane engaged in work on the harbour at Vera Cruz showing the friction grip tackle for placing the block in position

Mechanism of a Titan Crane

tons or more and they have been built to operate loads up to 60 tons. This type was evolved when the block system of breakwater construction came into general use. As is the case when Goliath cranes are employed, the concrete blocks are cast in special yards near the scene of operations and are wheeled on special trucks along the pier or gantry to a position near the crane. This picks up the blocks and swings them out into the position in which they are to be fixed in the breakwater. The blocks are then keyed together, as has already been explained, in order that they may present a solid front to the devastating action of the waves.

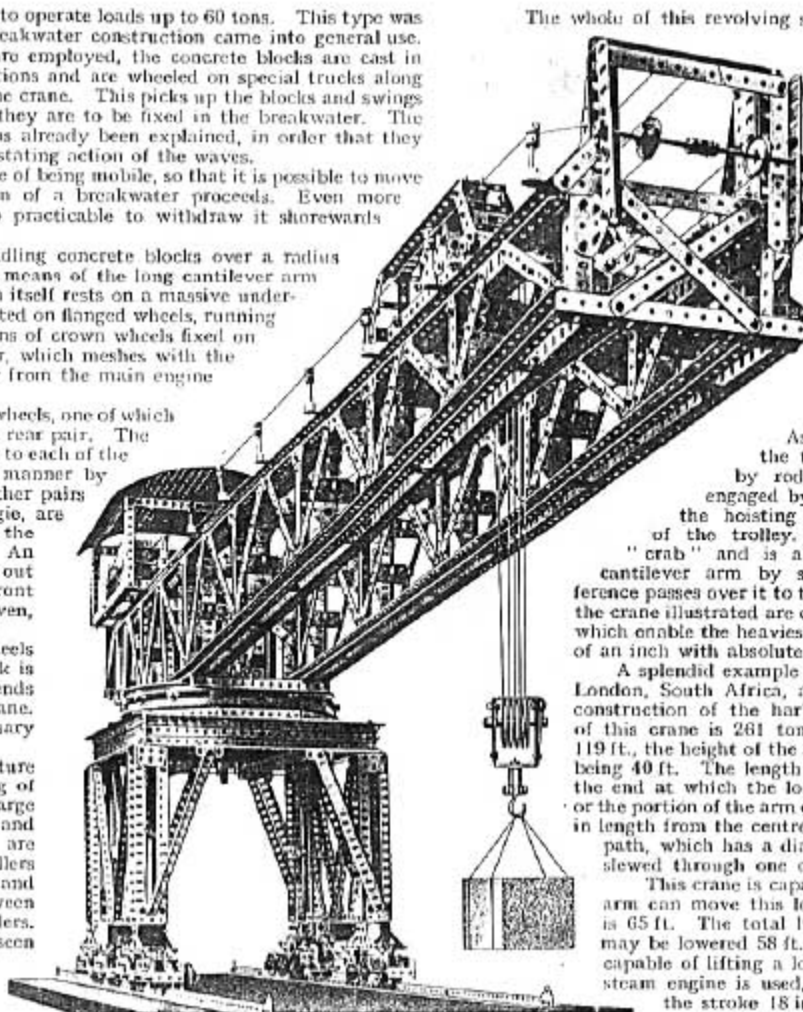
The Titan crane has the advantage of being mobile, so that it is possible to move it along the pier as the construction of a breakwater proceeds. Even more important is the fact that it is also practicable to withdraw it shorewards for shelter in bad weather.

These cranes are capable of handling concrete blocks over a radius of 100 ft. or more. They do this by means of the long cantilever arm that is mounted on a turntable, which itself rests on a massive under-carriage. The under-carriage is mounted on flanged wheels, running on a special track and driven by means of crown wheels fixed on the inside of the bogie. A bevel gear, which meshes with the crown wheel, transmits motive power from the main engine mounted on the cantilever arm.

The drive is taken to two pairs of wheels, one of which is the foremost pair and the other the rear pair. The drive from the same rod is transmitted to each of the two crown wheels in a very simple manner by means of small bevel wheels. The other pairs of wheels, the innermost on each bogie, are loose wheels and not connected with the driving mechanism in any way. An exactly similar arrangement is carried out on the other side of the track, the front and rear pairs of wheels being driven, and the two inner pairs being loose.

The practice of driving four wheels out of eight on each side of the track is simply one of convenience and depends largely upon the weight of the crane. In the lighter cranes it is not necessary to have four wheels to each bogie.

The cantilever arm and superstructure of all Titan cranes revolves on a ring of live rollers, which in the case of a large crane may have a path of between 30 and 40 ft. in diameter. The bearings are formed by a series of turned steel rollers held in position by a suitable frame and revolving on machined pathways between the upper and lower circular girders. The ends of the rollers can just be seen in the accompanying illustration of a Meccano model of a large block-setting crane immediately below the lower framework of the cantilever arm where it rests upon the massive metal mounting.



Meccano is engineering in miniature and a comparison of the above photograph with that on the preceding page shows how closely it is possible to construct models on the lines of real engineering practice.

Balancing the Huge Load

The whole of this revolving structure is centred by means of a large central pivot, consisting of a steel rod of considerable diameter. The revolving motion is transmitted from the engine, or—in the case of an electrically-equipped crane—from the electric motor, which occupies a corresponding position on the opposite end of the cantilever arm to that from which the load is operated. The weight of the engine or electric motor helps to balance the load, but it alone is not sufficient. A massive weight has also to be introduced to act as a counterpoise, and it is placed immediately beneath the engine housing.

The motion from the engine is transmitted through a chain of spur- and bevel-gears, which finally engage in the segmental spur track, formed around the exterior of the roller path. In some cranes the gears are thoroughly protected from the weather by covering them with heavy metal casings, but this is not always found necessary.

As previously explained, the same engine drives the travelling motion of the crane in a similar manner by rod and gearing. The gears are engaged or disengaged by the engine-man, who, of course, also controls the hoisting and lowering of the load and the movements of the trolley. This trolley—which is sometimes called the "crab" and is also known as a "Jenny"—is drawn along the cantilever arm by steel ropes and a lifting rope 4 in. in circumference passes over it to the hoisting block. The lowering arrangements in the crane illustrated are controlled by a patent system of hydraulic brakes, which enable the heaviest weights to be lowered within limits of a fraction of an inch with absolute precision.

A splendid example of the Titan type of crane is one erected at East London, South Africa, and which has played an important part in the construction of the harbour works and breakwater. The total weight of this crane is 261 tons. The overall length of the cantilever arm is 119 ft., the height of the top portion of the cantilever arm from the ground being 40 ft. The length of the arm from the centre to the nose—that is the end at which the load is operated—is 78 ft. 9 in., so that the tail—or the portion of the arm on which the engine-house is situated—is 40 ft. 6 in. in length from the centre of the arm. The crane arm revolves on a roller path, which has a diameter of 24 ft., and the arm is capable of being slewed through one complete revolution in three minutes.

This crane is capable of lifting a maximum load of 40 tons and the arm can move this load over an area the maximum radius of which is 65 ft. The total height of lift of the load is 30 ft., and the load may be lowered 58 ft. below the level of the track. The crane is thus capable of lifting a load over a total height of 88 ft. A two-cylinder steam engine is used, the diameter of the cylinders being 11 in. and the stroke 18 in.

The crab runs on four wheels and a lifting rope of 3½ in. circumference is used. The crab has a slow speed of 22 ft. per minute and a quick speed of 45 ft. per minute. Its hoisting

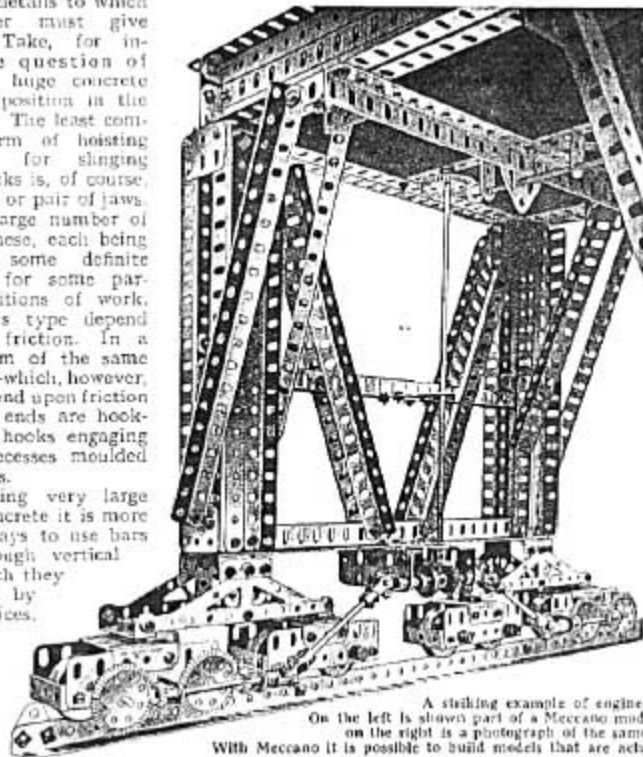
Block Lifting Devices

speed on slow gear when lifting its maximum load is 8½ ft. per minute, and its speed when racking on low gear with maximum load is 22 ft. per minute. The crane runs on 16 wheels, each of which is borne on springs. The width of the track from centre to centre of the rails is 17 ft.

Apart from the designing, constructing, and the erection on the site of the cranes themselves, there are many other details to which the engineer must give attention. Take, for instance, the question of slinging the huge concrete blocks into position in the breakwater. The least complicated form of hoisting arrangement for slinging concrete blocks is, of course, a simple clip or pair of jaws. There is a large number of designs of these, each being suited for some definite purpose or for some particular conditions of work. Clips of this type depend entirely on friction. In a modified form of the same type of clip—which, however, does not depend upon friction—the lower ends are hook-shaped, the hooks engaging in special recesses moulded in the blocks.

For lifting very large blocks of concrete it is more usual nowadays to use bars passing through vertical holes in which they are retained by various devices. Many of these are self-releasing. These are satisfactory when the blocks are to be set horizontally in a similar manner to that in which bricks are set in building a wall. In some breakwaters a more complicated setting is required, however, and the blocks are set at an angle or, as it is technically termed, "on the inclined bond." By setting the blocks in this manner, the breakwater is made to present a much more formidable obstacle to the rough seas than would be the case if the blocks were set horizontally.

The problem of slinging the blocks for setting on the inclined bond presents some little difficulty, which has been solved by an ingenious piece of tilting mechanism called "Fidler's Gear." This mechanism consists of a massive beam hanging



A striking example of engineering in miniature. On the left is shown part of a Meccano model of a Giant Block-setting Crane and on the right is a photograph of the same part in one of the real cranes. With Meccano it is possible to build models that are actual replicas in miniature of real engineering constructions.

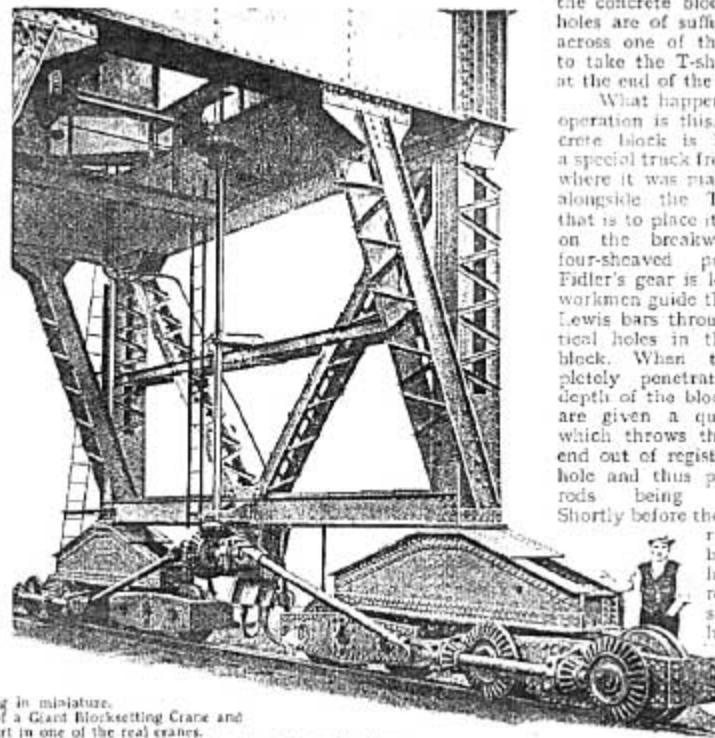
Setting on the "Inclined Bond"

from a swivelling joint, the whole suspended by a special four-sheaved pulley. The rotating movement of the beam on the swivel is controlled by a special worm gear, which meshes with a pinion wheel on the vertical swivel bar. A link hangs from the ends of each arm of the beam, which link supports steel cross-heads. From each of these cross-heads there hangs a long Lewis bar with a T end. Two perpendicular

holes run completely through the concrete blocks. These holes are of sufficient width across one of their sections to take the T-shaped pieces at the end of the Lewis bars.

What happens in actual operation is this. The concrete block is brought on a special truck from the yard where it was made and laid alongside the Titan crane that is to place it in position on the breakwater. The four-sheaved pulley with Fidler's gear is lowered, and workmen guide the T-shaped Lewis bars through the vertical holes in the concrete block. When these completely penetrate the full depth of the block, the bars are given a quarter turn, which throws the T-shaped end out of register with the hole and thus prevents the rods being withdrawn. Shortly before the Lewis bars

reach the bottom of the holes, the rollers on the steel-cross-heads take a bearing on the top of the block and roll across,



altering the relative positions of the points of suspension and the Lewis bars.

The signal is now given to the crane-man to hoist; the engine is started and the block is lifted at the exact angle at which it is to be set in position. The crane hoists the block, swivels round until the block is over its place in the breakwater, and then lowers it as is necessary. When the block rests on the breakwater, workmen turn the T-shaped rods until they are in register with the hole in the block. The crane again hoists and the Lewis bars are easily withdrawn, leaving the block in position set at the correct angle.

Cranes of this type have been employed in the construction of some of the

Destructive Power of Storm Waves

best-known harbours of the world, and they have played a very important part in the development of the Empire. Take, for instance, the case of Port Elizabeth, a seaport town some 400 miles east of Capetown. This is the second city in the colony and is situated on Algoa Bay, about seven miles south of the mouth of the Zwartkop River.

The Port owes its prosperity entirely to its harbour and it has become the centre for the trade of a great part of the interior of the country. Previously there were no convenient landing places and so it was impossible for ships to load or unload. Some improvements in this respect were made in 1881 when the old pier 800 ft. in length was constructed. Since that date even more extensive works have been carried out, and the harbour is now one of the finest in South Africa. Port Elizabeth is only one of dozens of similar instances of how giant block-setting cranes help trade.

Looking backward for a moment it is evident that, although progress in engineering has been extremely rapid in all directions in recent times, the development of great sea-works has been one of the most striking features in the history of engineering. As we have already noted, their erection requires great care and thought, as they are subject to continual hammering from the waves throughout the whole term of their existence.

People who only know the sea in its gentler summer moods often find it difficult to realise the destructiveness of the great storm waves. A heavy sea easily moves rocks and boulders weighing many tons. There are many well authenticated instances of this power. For instance, Sir William Matthews, the celebrated engineer, tells us that in 1898 a section of the Peterhead breakwater weighing 3,300 tons was moved bodily by wave action. In 1871 a harbour wall was built at Wick. It was composed of concrete blocks each weighing 100 tons and was capped by two tiers of 80-ton blocks. On top of all was a solid mass of cement weighing 800 tons. The engineers who built this massive structure were thoroughly convinced that it was capable of withstanding all wave action, but to their amazement the sea not only moved the whole mass but actually turned it round and deposited it inside the harbour! As if to show that it could do even more than this, the sea scattered the 80-ton blocks in all directions.

In due course the damage was repaired and the blocks were replaced. This time the engineers, determined to get the upper hand, placed on the top of the concrete blocks a superstructure more than three times as heavy as the original. Once more the sea took a hand in the game and before this 2,600 ton superstructure had been in position two years it was moved and broken in half.

The construction of works to withstand forces that are capable of creating such havoc would almost seem impossible. Nevertheless such works have been erected and their influence on trade and civilisation has been enormous.



Fidler's Gear ready for attaching to a concrete block



(Top) Concrete block held in position by Fidler's Gear. (Bottom) Meccano model of Fidler's Gear, which reproduces all the movements of the original



Development of British Shipping

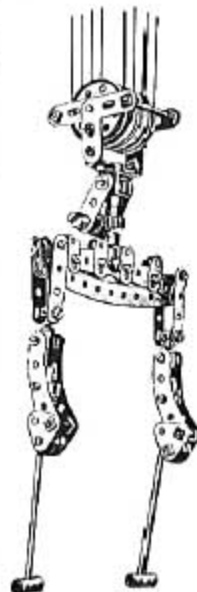
As a maritime nation Great Britain has always been closely concerned in the engineering problems involved in harbour construction. A few hundred years ago neither the Royal Navy nor the mercantile marine was of sufficient importance to require more harbour accommodation than that provided by the natural inlets and sheltered bays found at such places as Portsmouth, Plymouth, Weymouth, Falmouth and Dartmouth. We find, for instance, that in 1540 there were only four vessels of 120 tons burden registered in the Thames. In Queen Elizabeth's time the shipping of Liverpool amounted to only 223 tons, the largest vessel being of only 40 tons. How different are things to-day, when the shipping of the Thames exceeds 47,000,000 tons and that of the Mersey is nearly 26,000,000 tons!

When we turn to the harbour and dock accommodation provided at our great ports we find a similar change. At the beginning of the 19th century London had not a single dock, whereas to-day there are miles and miles of docks. The docks at Cardiff, Newport, Barrow, Middlesbrough and at many other places did not then exist. Even as late as 1816 Liverpool had only 16 acres of dock area, and Hull and Grimsby were no better than fishing ports, as far as their dock accommodation was concerned.

Taking our survey further afield, we find that the breakwater at Table Bay was not commenced until 1860; that until 1875 Calais Harbour had only 24 ft. of water on its bar at low water; that Colombo Harbour was not commenced until 1870; that Dover was not selected as a site for a great port until 1845; and that the breakwater at Newhaven was not started until 1878. We might extend the list indefinitely, showing that during the past century work in connection with harbour construction at home and abroad has gone forward by leaps and bounds, and has played a greater part than anything else in the development of civilisation in general and the world's trade in particular.

Even the enormous extensions of recent years have scarcely enabled dock engineering to keep pace with shipping, however. The harbour engineer has encouraged the production of larger vessels by providing better dock accommodation and in turn finds that he is called upon for further efforts. At Liverpool, for instance, the magnificent Gladstone Docks were opened in 1927 and are the largest docks in the world. They cover an area of 58 acres and have an entrance lock 1,070 ft. in length.

Thus the process of expansion continues. Larger docks lead to the production of bigger ships and for the safe handling of these still larger docks are demanded. It is quite clear that harbour-building machinery has not yet reached the limit of its development, and in future we may expect to see even larger cranes in use than the Titans and Goliaths of to-day.



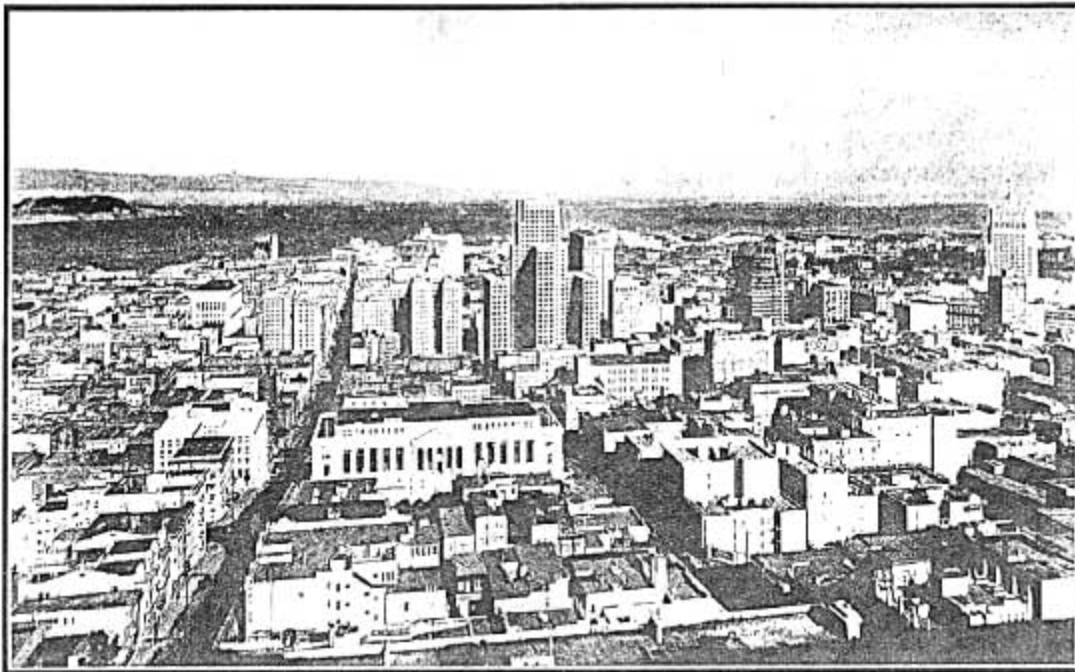
Meccano model of Fidler's Gear for comparison with original on the left of the page

Engineering of the Future

THE progress made in engineering during the past century has been so great that it seems scarcely possible that it can be maintained. Most of us are surrounded by such a mass of engineering achievements of all kinds that we are apt to overlook the fact that in spite of all these developments the engineer has had little opportunity of influencing the world as a whole. In a few countries his work is visible everywhere and his influence has been enormous. But with the exception of the United States these are mainly comparatively small European countries and there are enormous areas of the surface of the earth where one may travel for hundreds of miles without seeing anything but the crudest specimens of man's handiwork. Areas of this kind are to be found in crowded countries such as China as well as in the barren wastes of the Arctic and the Sahara Desert.

There is undoubtedly scope for an enormous extension of the activities of the engineer, even in the most unpromising regions. For instance, in many vast stretches of country the inhabitants until recently were dependent for water—the first necessity of life—on an uncertain and fluctuating supply from wells and streams. To-day this is all changed. Huge reservoirs have been constructed and dams erected across the beds of rivers making it possible to maintain an ample supply of water in even the driest seasons. Difficulties due to climate and local conditions have been successfully overcome and the water retained by the gigantic dams has been turned to good use in reclaiming desert areas and in preventing fertile ground from being wasted for lack of water when the rains failed. It is interesting to note that these gigantic schemes have been carried out by British engineers.

Similarly the improvements in the means of transport that have been developed on each side of the north Atlantic Ocean are being extended slowly to other parts of the world. The advent of the steam locomotive in any new country necessitates



In the city of the future, buildings will be larger and higher than they are to-day. This photograph of San Francisco shows the business quarter of that city with the wonderful bay in the distance, and suggests how development will proceed.

be expansion. Railways and roads will spread in all directions in fertile lands to enable the inhabitants to dispose of their produce. Manufactures will follow and the rivers will be harnessed to generate electric power on a vast scale.

As a result of this extension a large demand will certainly arise for materials for the building of bridges, the construction of dams and other works, and eventually this will lead to standardisation of parts and practically to mass production.

Take bridge-building for example. At present the building of great bridges, such as those now being erected to span Sydney Harbour and the Hudson River at New York, is the work of years. When the site and the design of a bridge have been finally settled it is usually necessary to erect special workshops in the neighbourhood and often also to devise new methods and machinery to facilitate the work. Compare this with the task of building a new railway bridge over a narrow country road. Girders and plates of the required size are transported to the spot, and at the appointed hour workmen commence to demolish the old bridge and to

the building of bridges, and the boring of tunnels; the arrival of the motor car demands the construction of roads; and with the coming of the aeroplane arises the necessity of providing safe landing grounds.

Although engineers have been busily engaged in the necessary work to meet these demands an observer looking at the Earth from the outside would not be greatly impressed by the results. In a few countries he would see the means of production, machinery, railways and shipping well developed; in other countries he would see the beginning of efforts to supply this demand; but elsewhere he could not fail to be struck by the fact that millions of people are still dependent for their living on the almost unaided efforts of their own hands.

It is the task of the engineer to alter this and there is no doubt that the bulk of his work in the immediate future will

Bridge Building with Standard Parts

place each portion of the new bridge in position. Everything is then made secure and in a few hours trains once more may pass over the bridge which may be said to have sprung into existence ready-made.

Why should not this be done with any bridge irrespective of size? The chief forms of design are by this time well known and understood, and it is surely not too much to hope that some bridge-building genius will devise systems of construction that will enable any bridge to be built up from easily made standard parts just as models of them may be built up from standard Meccano parts.

The suggestion of the application of mass production methods to bridges as large as, say, the Quebec Bridge over the St. Lawrence River may, at first sight, appear somewhat absurd. It is true that there is no great demand at present for large bridges of this kind, and a commercial traveller carrying samples of them would do well if he made one sale in ten years! Further, the cost of laying down plant to make the necessary standard parts would be very great. It must be remembered, however, that exactly similar objections were made to Henry Ford's schemes when he entered the motor car industry; but he persevered because he was convinced that standardisation would mean price reduction and that in consequence a huge market for his cars would be created.

A little thought will show that there is still enormous scope for bridge-building even in Great Britain. A bridge across the Mersey comparable to the Hudson River bridge would be of enormous benefit. Similarly we find South Wales cut off from south-western England, Kent from Essex, and East Yorkshire from Lincolnshire by waterways that easily might be bridged nearer their mouths. Even a bridge across the English Channel is by no means an impossibility.

Another important point is that as a rule bridges are not erected until they are absolutely forced upon us. A world governed by wise engineering principles would foresee the necessity or the advantages to be gained and would proceed to build with the aid of standard parts. It is because the line of the Canadian Pacific Railway was carried across the continent before necessity compelled its completion and in anticipation of succeeding developments that this railway deserves to rank as one of the greatest engineering developments in the world.

Standardisation of parts would be made easier by the introduction of new building materials. At present we are living in the age of iron but in many respects iron is an unsatisfactory metal. It is used on such an enormous scale in industry and in constructive engineering because we do not know a more



The skyscraper cities of the future will not be ugly. Their iron and concrete buildings will be at once graceful and useful, as this photograph of the City Hall of Los Angeles shows.

A Successor to Iron and Steel

suitable metal, but it has the great drawback of being easily corroded and rusted. It has been calculated that the annual loss from rusting and corrosion amounts to no less than £500,000,000, and yet the only practical method that has been available until recently for protecting iron from rusting has been the liberal use of paint. The comparatively recent introduction of rustless steel may possibly put an end to this waste and maintain the present position of iron as the world's primary structural metal. Rustless steel is really an alloy containing about 13 per cent. of chromium. It is resistant to most forms of corrosion and is likely to find an increasing number of industrial applications such as in hydraulic pumps, and in dock, bridge and ship construction.

Another important point in connection with the use of iron is that there is a limit to the amount of the metal available. A well-known geologist has stated that if the world's consumption of iron continues to increase at the same rate as before the War, the supply of ore probably will be exhausted within 130 to 150 years. This suggests that the time is approaching when a substitute must be found.

It is difficult to say what new metal or alloy will be developed to take the place of iron and steel. Aluminium or magnesium may come into extensive use in some form or other, as alloys containing them combine lightness with other valuable qualities, and research work may result in the production of alloys having the necessary strength.

As far as reservoir and dam construction and, in a less degree, bridge-building are concerned, the use of reinforced concrete makes standardisation comparatively easy. Ferro-concrete blocks of standard sizes may be made without any difficulty wherever they are required, or alternatively concrete may be poured directly into its final position by making use of standard moulds. This method has been introduced already in America where it is employed in the erection of the huge buildings for which that country is famous. Another interesting and important feature of concrete is that its introduction will help in conserving the supply of iron. A considerably less amount of the metal will be required and in addition it will be protected by the concrete in which it is embedded from the corroding effect of moist air.

The future of engineering must be looked at also from another point of view. The great extensions to which we have referred will not only call for a larger number of trained engineers than are to be found at the present day but will result also in a much more intense study of the science. This study will be carried on by generations that will be more familiar with engineering methods than the present generation,

Future of Transport

and we may note in passing that the growing tendency to think in engineering terms is being strongly encouraged by familiarity with the Meccano system of miniature engineering. This study, together with research on the composition and properties of materials of all kinds, will undoubtedly lead to the discovery of new principles and the application of old principles in new forms.

It is impossible to say what new principles will be developed but it is probable that these will be as startling to those who live to see them as the mechanical and electrical methods now in use would be to our ancestors. It must be remembered that the introduction of coaches with glass windows was considered wonderful in the days of Charles II, while at a later period the substitution of stage coaches by railways was regarded as an absolute revolution. The spread of the iron road was thought to be a conquest that involved the complete decay of road travel, but eventually there came another surprise when the motor car made roads more important than they had ever been before.

Surprises of this kind are probably in store for us in the future also. The average prophet visualises the future as bound up with the aeroplane and imagines that the time is coming when passengers and goods will be carried through the air almost to the exclusion of present-day methods. No doubt aeroplanes will be so much improved from the point of view of stability, range and carrying power, that flights round the world will be less exciting than a voyage in a 50,000 ton ocean liner is to-day. But it is far more probable that greater use than ever will be made of improved methods of transport on land and sea. The engineers of civilized races never allow any of their achievements to go to waste. They may allow them to lie neglected for a time, but are always eager to seize any opportunity of improving them. The work of the famous men who built roads in England towards the end of the eighteenth century was not ruined by the coming of the railway, for instance, and it was on the basis of their work that the task of reconstruction and extension was commenced.

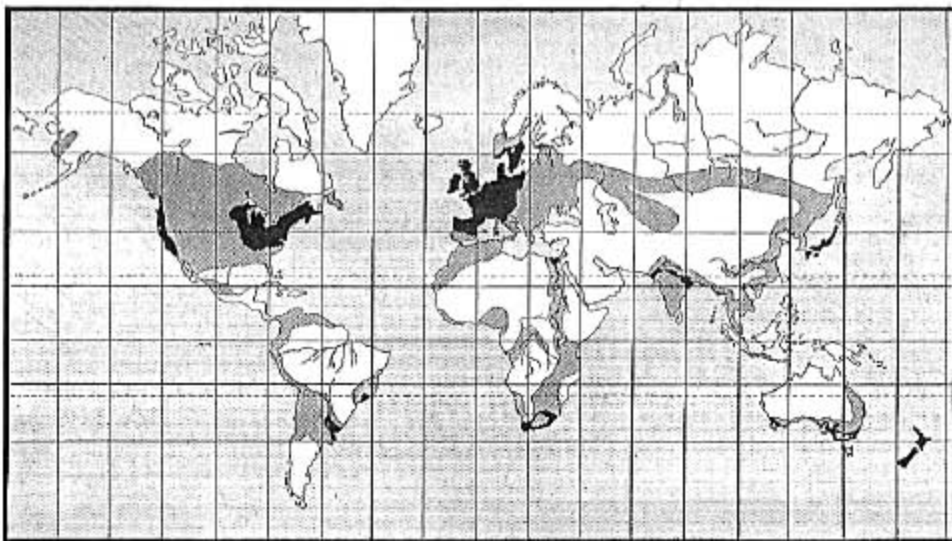
What form will transport on Earth take? It has been suggested that some form of moving way will provide the means of travelling in the future, and that it will be possible to travel from London to Liverpool, for instance, by simply stepping on to a series of platforms moving between the two cities like endless belts. These platforms will move at varying speeds in order that passengers may first

Possibilities of Moving Roadways

board the slowest and work up to the fastest by stages that do not involve any sudden and uncomfortable increase in speed. Presumably these moving ways would be furnished with adequate waiting-rooms and lounges in order that journeys may be made in comfort at least equal to that of the present-day Pullman coach.

Methods of this kind undoubtedly would prove very valuable especially within the restricted area of a large community or city, but it is doubtful whether they will ever be developed for long-distance communication. They would involve the construction of enormous power plants together with bearings and flexible joints possessing a capacity at present undreamed of for resisting wear and tear. It is true that these requirements may be met as the result of further experiment and research but it seems probable that more economical and equally satisfactory results may be obtained by developments of the moving vehicle and stationary road system at present in use.

The inevitable increase in the speed and volume in vehicular traffic on roadways will bring about a dangerous condition of affairs to cope with which two-way traffic will be abolished in favour of the "one track, one direc-



On the above map the black areas show where the engineer has been at work for a considerable period, and the shaded portions indicate where he is now penetrating. Engineering developments in lands left white have not yet begun. It will be seen that the area over which the influence of the engineer has been exerted in any notable degree is very small, compared with that awaiting his attention.

tion" method in use on the railways.

Another interesting point concerns the fight between the rubber-tyred wheel and the wheel designed to run on rails. The struggle will probably be won by the latter, for two reasons. In the first place, the population of the Earth will undoubtedly increase so greatly that there will be no space left available for rubber plantations, every possible acre of ground being required for food-producing purposes. Secondly, the future development of light alloys already referred to will make the production of rails and metal wheels on a large scale a comparatively easy matter.

The victory of the rail will be accompanied by the abolition of the double rail in favour of the single rail with streamlined mono-cars balanced by a gyroscope. The rails on which these cars will run will vary considerably in size to suit varying weights of traffic and an elaborate network of them with properly constructed junctions will cover the country in all directions. The private owner of a mono-car may have rails leading from his garage to the public rails or if he has not, he will be able to place his car on the latter quite easily, as its metal parts will be made of some light alloy and the remainder would be constructed of fabric of little weight.

Coming Era of the Mono-Car

Difficulties of transmission of power over long distances will have been overcome in one way or another by the time that mono-cars have been fully developed, and the single rail may be made to serve as a medium for the supply of electrical power to the gyroscope and to the motor that drives the car. The latter would seem absurdly small to a motorist of the present day, who is accustomed to the heavy masses of metal constituting the petrol engines, gear-boxes and back axles of the cars that now rank as the last word in engineering. But the reduction in weight brought about by the use of light alloys and by the absence of dead weight in the shape of gearing, fuel and cooling water will make a very small-powered motor quite sufficient to propel the mono-car of the future at very high speeds.

In addition to the small privately-owned cars there will be larger ones available for public use. These will be constructed on somewhat similar lines, but extra provision will be made for the comfort and well-being of the passengers of the future, who, no doubt, will examine the finest of our Pullman coaches reposing in their musenets with feelings of surprise that human beings actually travelled in what would seem to them uncomfortable wagons that lurched and staggered at the absurdly low speed of 60 miles per hour!

Turning from land travel to transport by water, it is certain that sea-going vessels will be larger and more commodious. Standardised systems of construction will no doubt be adopted to reduce their cost and the time spent in building them, while their machinery will certainly be much more compact and powerful. The exact form it will take will depend very largely on the future fuel supply, but there

New Methods of Ocean Transport

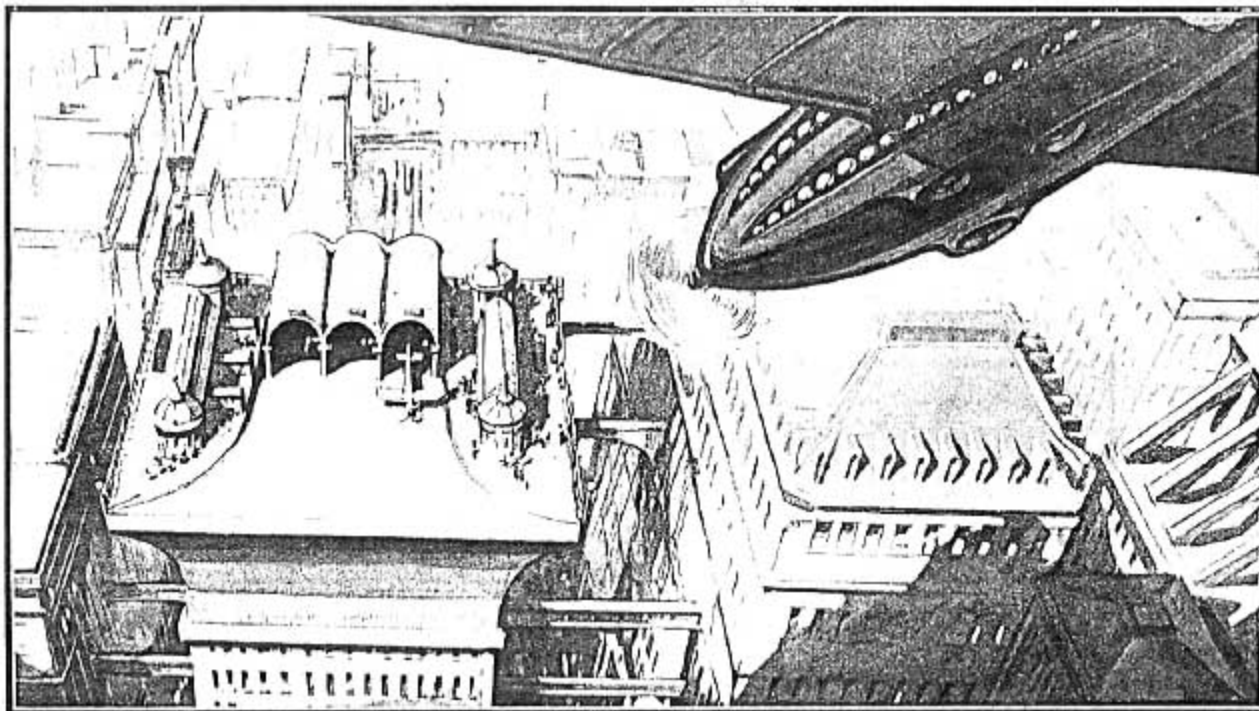
is no doubt that some of the steps of present existing between the source of power and the final impelling system will be either abolished or simplified considerably.

It is not altogether impossible that cables will stretch across the ocean, from

which ships may pick up current to drive electric motors. Vents that were really more startling than the provision of such wires have often been accomplished by engineers in the past, and the attempt that is to be made to place a string of floating landing-stages across the Atlantic Ocean like stepping stones may eventually lead to developments of this kind. But if ships continue to run under their own power a form of Diesel engine with electrical transmission seems likely to become prominent and will no doubt hold its own for a considerable period.

The time

is approaching, however, when oil as well as coal will fail us. The exhaustion of the supply of these important fuels is not a matter for alarm. Other sources of power will be discovered, or to make a more accurate statement, other methods of using the power derived from the Sun's heat. At present we make use of this immense source of power in a really crude and second-hand fashion. We have begun to make use of such sources of natural power as waterfalls, and probably the time is not far distant when the power of the tides and winds will also be utilised. These indirect methods of using Sun power are not wasteful, but they are somewhat capricious. In time to come more direct methods will be brought into use under the compulsion of necessity, and the total horsepower that will then be available will be immeasurably greater than that with which we struggle on to-day.



A forecast of a city of the future. Skyscrapers of enormous size will be inter-connected at various levels by roadways and possibly railways, thus relieving the streets below of a great deal of traffic. The building of roadways to connect skyscrapers in this manner has already been seriously suggested in more than one American city. The air passenger of the future will be rushed swiftly upward in an electric elevator to the flat roof of one of these giant buildings, where he will find a completely equipped aerodrome with air liners leaving for, or arriving from, all parts of the world.

Mighty Power Plants in the Tropics

In the days when we rely upon the direct heat radiated by the Sun, plants for power production will be more concentrated. Instead of myriads of little power plants, some obsolete and many inefficient, scattered over the surface of the Earth, there will be several stations distributed around the Earth on or near the equator, where the Sun's radiation is most powerful. The heat concentrated by mirrors or lenses of super-glass will be used to evaporate a liquid in boilers, and the pressure of the resulting vapour will be utilised in giant cylinders.

The liquid used will certainly not be water. At present water is used because it is cheap and plentiful and its boiling point is not inconveniently high. We are so thoroughly accustomed to the use of steam in engines that a suggestion to use any other liquid than water comes with something of a shock. But from an efficiency point of view, better results would be obtained from mercury. This is an expensive liquid with a high boiling point, but it has nevertheless been found possible to use it on a commercial scale for power production, the vapour being condensed after leaving the working cylinders and the heat thus liberated used for steam production. Other liquids may be discovered to have thermal properties equal to those of mercury, and with greater experience in building boilers and cylinders to withstand higher temperatures, there seems little doubt that one of these will come into use instead of water.

The power produced by the great plants to be erected in the tropics must then be transmitted to other regions of the Earth. The form in which the transmission will be made will depend very largely upon the purpose for which power is required. Electricity will certainly play a very important part, and already it is comparatively easy to transmit high-voltage current to enormous distances by cables. Attempts have been made to do this without wires, but so far there seem to be serious difficulties in the way of wireless power transmission, the amount of power received at any one place being a very small fraction of that radiated. Some development of the beam system may solve such difficulties, or an entirely new method may be introduced; but in any case great modifications will be necessary in wireless apparatus if a really satisfactory proportion of the power developed

Aeroplanes propelled by Liquid Air

at the generating station is to reach a distant point in this manner.

Wherever transmission of electricity by wire or any other means is possible, this method of power distribution will no doubt be adopted. But for an aeroplane propulsion, and for ships, either surface or submarine, liquid air may prove to be valuable. It may be produced in compressors at the great power plants near the

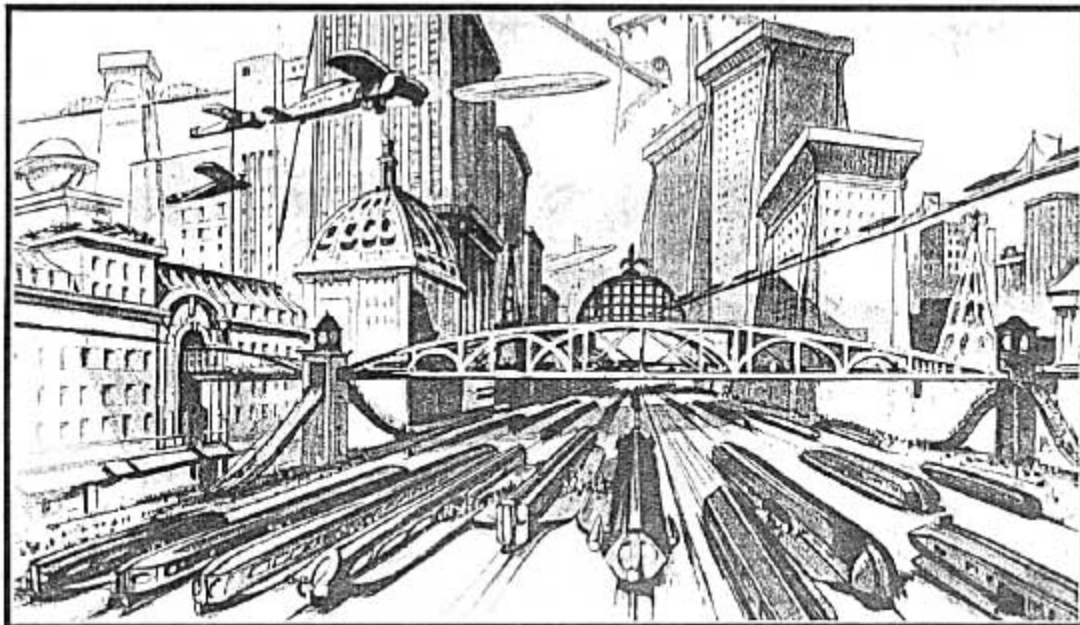
equator and stored under pressure in cylinders that are easily transportable.

This power medium may be used in two forms. In one it will be allowed to expand in some kind of turbine, where, because of its enormous pressure, it will be far more effective than steam is at the present day. For an aeroplane, in which additional weight makes additional power necessary, machinery and propellers will be omitted altogether, the liquid air being allowed to expand through nozzles directed to the rear of the planes, to propel it forward like a rocket. This is by no means a visionary scheme and suggestions for using liquid air in this manner have already been made. Its use is not, of course, feasible at the present day on account of its high cost.

The fantastic stories that we often read of the enormous power that will be obtained in future from

the disintegration of atoms may be disregarded. It is quite true that the temperature of a chunk of radium is higher than that of its surroundings, and that this remarkable source of heat continues to operate for incredibly long periods. A few tons of radium would thus be very valuable—but so far the total amount that has been extracted is only one pound, and there is no indication that any such quantity as a ton exists in the Earth within easy reach.

It may be noted that we do actually make use of the energy of disintegrating atoms, as this source of energy seems to play a great part in maintaining the temperature of the Sun. To make use of it directly is another matter altogether. Very few elements radiate energy of this kind spontaneously, and while there is no doubt whatever that enormous stores of energy lie within all atoms and would be available for use in some form if liberated by their break-up, it would require more energy or power to decompose them than would be set free. On the average the cost is at present something like 100,000 times the gain!



Perhaps Piccadilly will look like this in the year 2000, with lines of fast suburban electric trains taking the place of the motor traffic of the present day.

Development of Skyscraper Cities

The break-up of atoms of aluminium may be taken as an illustration of this. This metal would yield the inflammable gas hydrogen on bombardment with the rays from radium. But if the rays from the entire stock of radium in the world were projected into a sheet of aluminium for the next seven years, only one cubic millimetre of hydrogen would be produced. We can find better uses for radium than this.

Summing up, it may be said that the two things that the engineer calls for in all circumstances are ample supplies of improved materials and power. We have seen how these wants will probably be supplied, the former by standardisation and research on non-rusting metallic alloys, and the latter by making more direct use of the Sun's heat. With his resources thus increased, the engineer will continue to play an increasingly important part in life.

In future we shall live in cities that will be planned and erected by engineers, who have already invaded the building world in America. The great heights to which the steel and concrete erections of American cities have been taken is a measure of what will be done throughout the world as the population increases. The difficulty of supplying clean fresh air to those who live and work on the lower floors of the great buildings will be solved by the use of carefully planned ducts through which filtered air will be supplied, while lamps that radiate a scientific blend of infra-red and ultra-violet rays in addition to the usual light rays will be more beneficial to them than sunlight itself.

The continued increase in the number of people per square yard in crowded business and residential areas will also make the provision of overhead means of transport necessary, as may be realised from the fact that if the Woolworth Building and other skyscrapers on Manhattan Island in New York discharged all their occupants at once there would not be standing room for them in the streets in the immediate vicinity. The buildings of the cities of the future will therefore be connected by bridges at various heights for foot and vehicular traffic so that it will not be necessary for all their occupants to follow the same route in entering or leaving.

High-speed escalators will be provided, in addition to express lifts, and if the occupant of an office on the fiftieth floor of a building near the Bank of England in London gets tired of travelling to his home north of Hampstead on the mono-rail cars that run through the city at different levels, he may proceed by a series of

Meccano Boys—Engineers of the Future

escalators that take him north while bringing him nearer the ground.

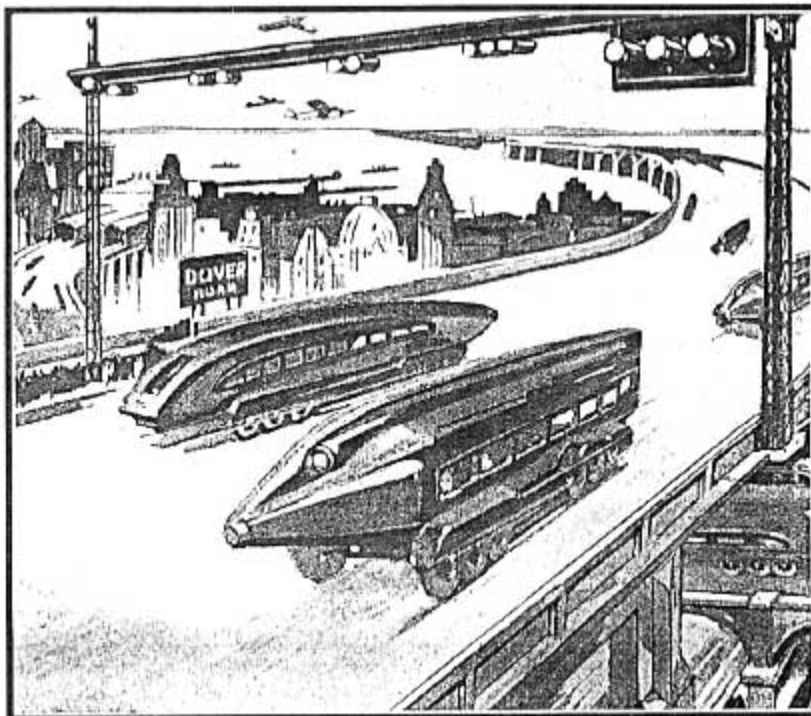
A suggestion of this kind has already been made quite seriously in Chicago, a go-ahead American city that promises to produce many splendid ideas in the future. It has been proposed to erect a line of skyscrapers along the Lake Michigan frontage of that city, with the tallest buildings in the middle of the line, the heights decreasing towards the ends. The

tops of these buildings will be bridged by a roadway, along which those who work in the buildings will pass on arrival or departure, while they will leave their cars during the day in the garages arranged on the uppermost floors. A scheme of this kind will relieve congestion of traffic in the streets and thus prevent waste of valuable time.

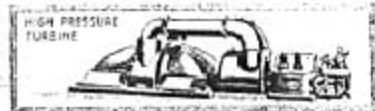
The engineer will also rule in factories and in agriculture. In the former he will find new methods of carrying out the fundamental processes, and he will be greatly assisted in this work by the results of a more scientific study of lubrication as well as by the new alloys that the metallurgists will produce. Agricultural machinery is in special need of improvement, but at present the lack of power prevents developments. Both steam-engines and petrol motors are being used more frequently, but the complete mechanization of this industry will not become possible until cheap electrical power is widely distributed.

The last place in which power on any comprehensive scale will be introduced is the home, but in the days to come power will be so cheap in comparison with human labour that the latter will be displaced almost universally. There is, in fact, no sphere where the efforts of the engineer will not be productive, for in addition to his utilitarian work he will join forces with others to give practical expression to many ideas and discoveries that will add greatly to the enjoyment of life and increase the general standard of comfort.

This brief summary of the engineering of the future is necessarily incomplete. In 1828 George Stephenson was in a position to visualise the great changes in transport methods that the introduction of the steam engine would bring about, but he would have been quite unable to foretell the introduction of the petrol engine, and of electric lighting and power. Similarly, principles that to us would be new and startling will almost certainly be commonplace features to the engineers of the future, who are the Meccano boys of to-day.



An impression of the great land liners of the future, careering along special elevated roadways, the triumph of the engineer.



The Boyhood of Famous Inventors

Most of the world's famous inventors and engineers showed their love of mechanical subjects in their young days. How they would have welcomed Meccano then! The schoolboy, James Watt, amazed his friends by building a small electric shocking-machine, therein displaying that love of "making things work" that afterwards led him to fame and fortune as the inventor of the first practical steam engine. Samuel Smiles, in his biography of John Smeaton, the famous lighthouse builder, tells us that "the only playthings in which he seemed to take any real pleasure were models of things

that would work." Young James Nasmyth, the future inventor of the steam hammer, spent hours in laboriously turning wooden spinning tops and making small brass cannon. George Stephenson, during most of the little spare time he had when a boy, constructed models of pumping and winding engines out of clay. Edison, as a boy, experimented with a telegraphic instrument in which the wires were wrapped in old rags and glass bottles served as insulators. How much easier would the tasks of these famous men have been had they had Meccano to assist them with their experiments!

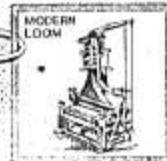
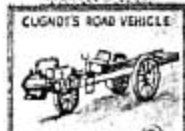
The Joy of Inventing

Inventing new models and movements in Meccano is the greatest fun in the world, and there is little doubt that the inventors and engineers who will make their mark in the future are at the present moment building Meccano models.

note that many large engineering firms always keep a stock of Meccano on hand with which to carry out experiments and to test new ideas.

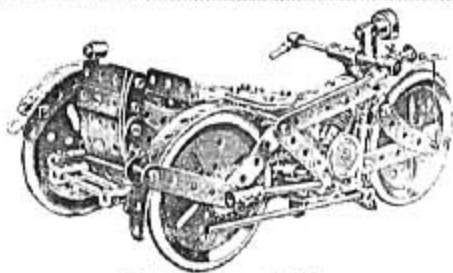
As soon as he has built all the models shown in the Manuals, every Meccano boy should set about improving them or building others according to his own ideas. New and valuable parts are constantly being added to the Meccano system and each enables boys to build a whole series of new and better models.

Every Meccano boy should try his hand at inventing, for there is nothing in the world comparable with the joy and satisfaction of creating something new. When he succeeds in producing a new model he should enter it in one of the Meccano Model-building Competitions, announced every month in the "Meccano Magazine." Splendid prizes are waiting to be won by inventive boys!



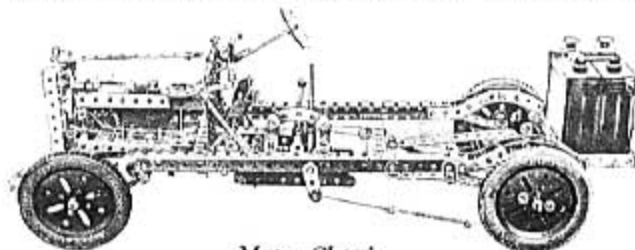
MECCANO

A SELECTION OF SUPER MODELS



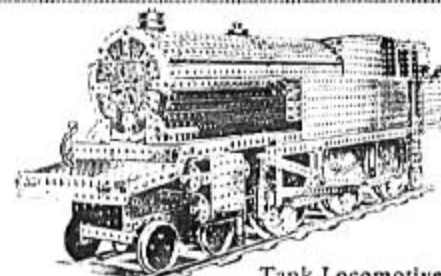
Motorcycle and Sidecar

This is an excellent example of Meccano miniature engineering. The Sidecar is of streamlined design and is mounted on springs. The Motorcycle is complete with lamps, horn, exhaust pipes, spring-mounted saddle, etc.



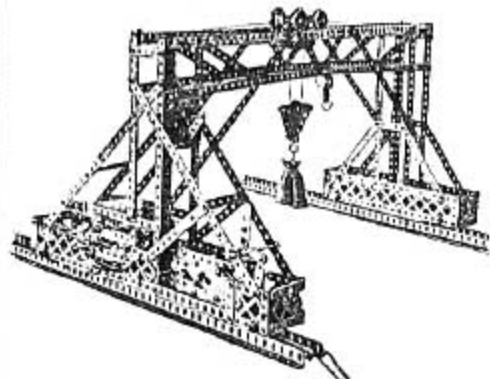
Motor Chassis

Replicas of this model are used by motor car manufacturers and agents to demonstrate to car buyers all the movements of a first class automobile. The model runs perfectly under its own power.



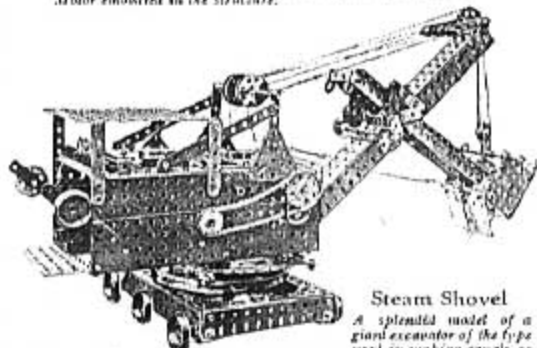
Tank Locomotive

Here is a model that will delight the railway expert. A very interesting feature is the accurate reproduction of Walschaert's valve gear, every detail of which has its counterpart in the Meccano model.



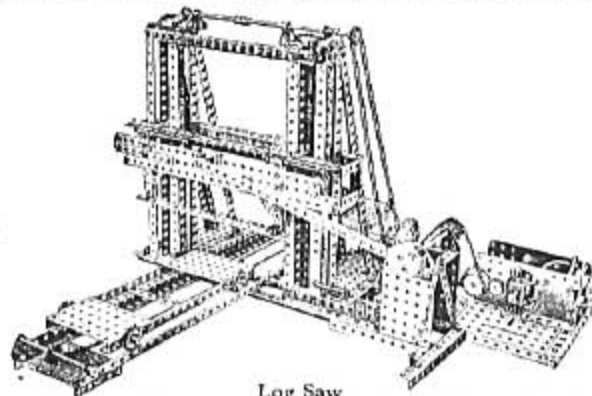
Travelling Gantry Crane

This is a realistic and powerful model. It demonstrates a number of interesting movements, all of which may be actuated separately or simultaneously by means of the 4-volt Electric Motor embodied in the structure.



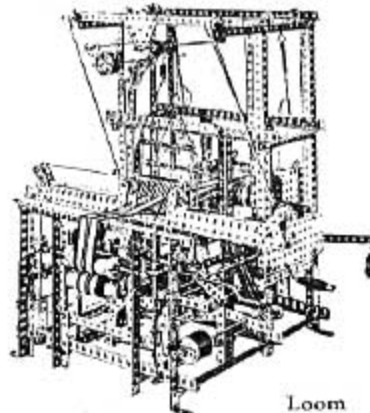
Steam Shovel

A splendid model of a giant excavator of the type used in making canals or railway cuttings. The travelling and rotating movements and luffing motion of the job are operated by an Electric Motor.



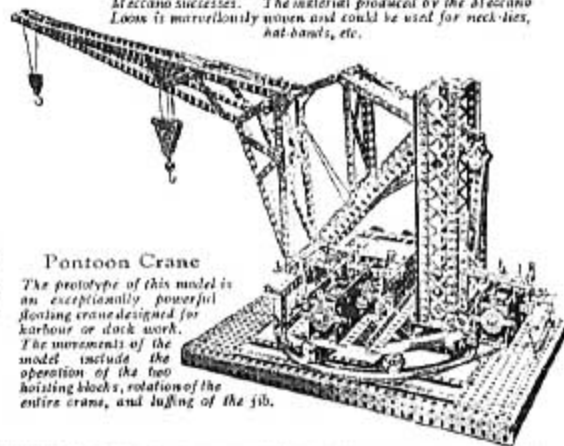
Log Saw

This is a model of a machine used in saw mills for the preliminary cutting and shaping of the tree trunks as they arrive from the logging camps. The saw is driven rapidly to and fro whilst the work table travels slowly beneath it.



Loom

This is perhaps the crowning achievement in the long list of Meccano successes. The material produced by the Meccano Loom is marvellously woven and could be used for neck-ties, hat bands, etc.



Pontoon Crane

The prototype of this model is an exceptionally powerful floating crane designed for harbour or dock work. The movements of the model include the operation of the two hoisting blocks, rotation of the entire crane, and luffing of the jib.

MECCANO

The Toy that made Engineering famous

Engineering for Boys

The Meccano system is composed of over two hundred different parts, mostly made of steel or brass, each one of which has a specified mechanical purpose. These parts combine to form a complete miniature engineering system with which practically any mechanical movement may be reproduced in model form. More can be accomplished with Meccano than with any other constructional toy, for no other system has such possibilities. The genius is in the parts and the youngest boy can commence to build models as soon as he gets his Outfit home.

Hundreds of Models

There is no limit to the number of models you can build with Meccano—Cranes, Clocks, Motor Cars, Ship-Coalers, Machine Tools, Locomotives—in fact everything that interests boys. The most wonderful thing about Meccano is that it is *real engineering*; it is fascinating and delightful and yet so simple that even an inexperienced boy may join in the fun of building models without having to study or learn anything. A beautifully illustrated Book of Instructions showing how to make hundreds of models is included with every Outfit and a screw-driver is the only tool required.

Meccano Boys Build and Invent

The training of the eye, brain and hand in erecting Meccano is considerable, but there is also developed a faculty of immense value to every boy. No boy is content to build the models exactly as he finds them; it is always possible to improve, and he sets to work to do this almost at once. It is a boy's nature to venture into unknown fields, and the Meccano hobby opens up a new and wide world for him to explore. He very soon proceeds to invent, and new models and designs, the creation of his own brain, make their appearance.

How to Begin

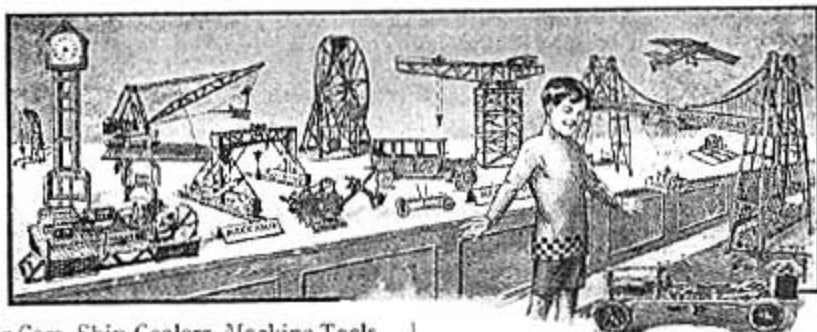
Meccano is sold in nine different Outfits, numbered 00 to 7. All Meccano parts are of the same high quality and finish, but the larger Outfits contain a greater quantity and variety of parts, making possible the construction of more elaborate models. Each Outfit may be converted into the one next higher by the purchase of an Accessory Outfit (see page 41). Thus, if a No. 2 is the first Outfit bought, it may be converted into a No. 3 by adding to it a No. 2A. A No. 3A will then convert it into a No. 4 and so on up to No. 7. In this way, no matter with what Outfit you commence, you may build it up by degrees until you possess a No. 7.

Meccano parts may be bought separately at any time in any quantity (see illustrated list at end of this book).

The Meccano Service

The Meccano boy of to-day will be the famous engineer of tomorrow. When you want to know something more about engineering than is now shown in our books, or when you strike a rough problem of any kind, write to us. We receive over 200 letters from boys every day all the year round. Some write to us because they are in difficulty, others because they want advice on their work or pleasures, or about their choice of a career. Others, again, write to us just because they like to do so—and we are glad to know that they regard us as their friends. We publish a special Magazine for them (see page IV of cover).

Although all kinds of queries are addressed to us on all manner of subjects, the main interest is, of course, Engineering. No one has such a wonderful knowledge of engineering matters as that possessed by our staff of experts, and this vast store of knowledge, gained only by many years of hard-earned experience, is at your service.



THE FINEST HOBBY IN THE WORLD

MECCANO



No. 00 Outfit

The No. 00 Outfit is specially adapted to the requirements of very young boys. A special Manual of Instructions is included in the Outfit showing how 116 interesting models may be constructed, each capable of providing hours of fun. A selection of the models that can be built with No. 00 Outfit is illustrated on this page.

Price 3/6

A No. 00A Accessory Outfit will convert a No. 00 into a No. 0 Outfit. See page 41.

ENGINEERING FOR BOYS

MECCANO



No. 0 Outfit

The No. 0 Outfit contains a splendid assortment of Meccano parts, and a special Manual of Instructions giving examples of 184 models that may be built with the Outfit. An assortment of these models is illustrated on this page.

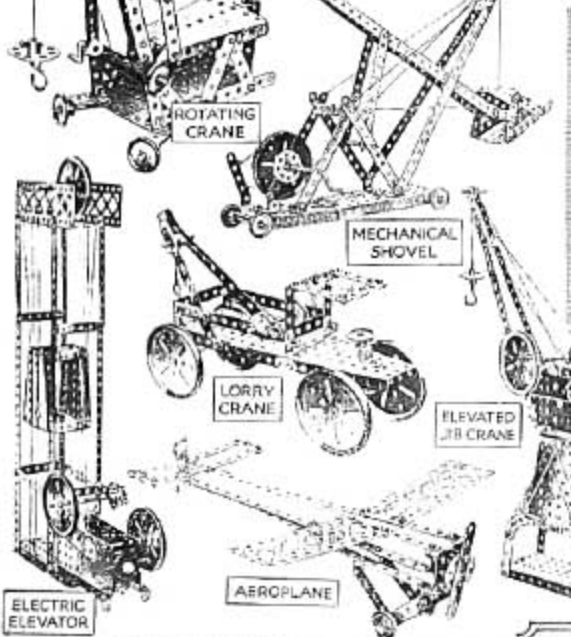
Everything necessary for commencing to build immediately is included in the Outfit.

Price 5/-

A No. 0 Accessory Outfit will convert a No. 0 into a No. 1 Outfit. See page 31.

RICHLY ENAMELLED IN COLOURS

MECCANO

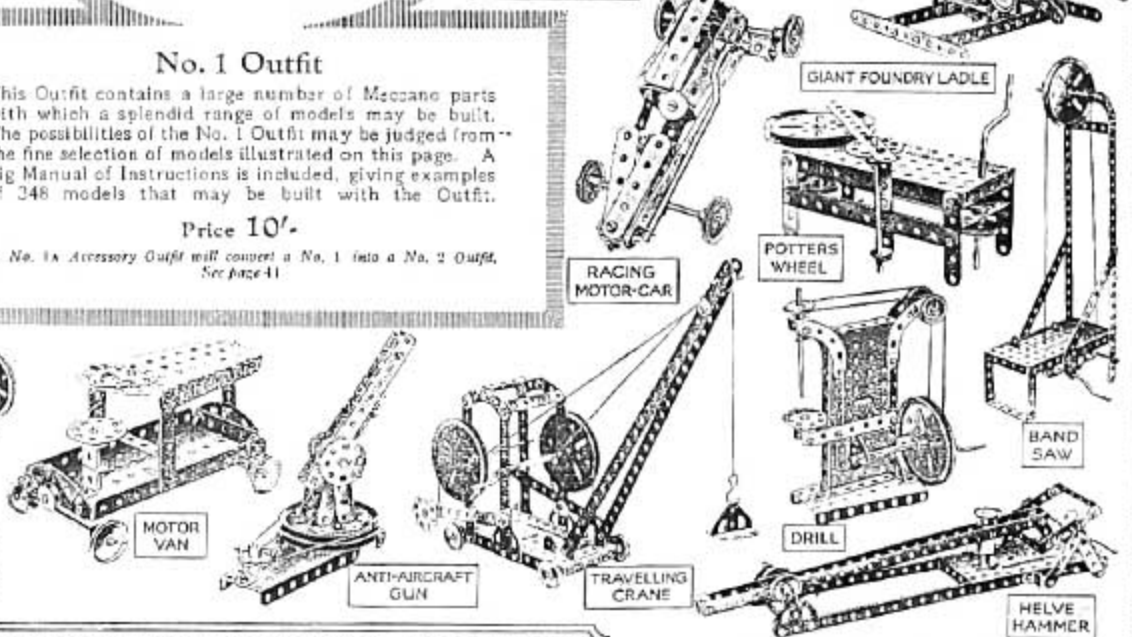


No. 1 Outfit

This Outfit contains a large number of Meccano parts with which a splendid range of models may be built. The possibilities of the No. 1 Outfit may be judged from the fine selection of models illustrated on this page. A big Manual of Instructions is included, giving examples of 348 models that may be built with the Outfit.

Price 10/-

A No. 1A Accessory Outfit will convert a No. 1 into a No. 2 Outfit. See page 41.



NEW PARTS. BETTER MODELS. MORE FUN.

MECCANO

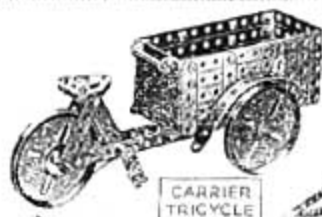


No. 2 Outfit

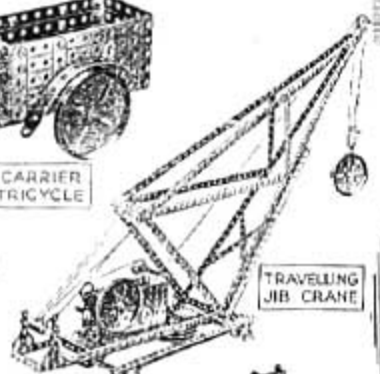
The fortunate possessor of a No. 2 Outfit is able to build up models of a more complicated and interesting type. A selection of these fine models is illustrated on this page. All the models are designed on correct engineering principles, and full instructions for building 396 are included in the Outfit.

Price 16/-

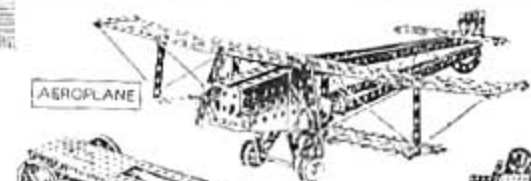
A No. 2A Accessory Outfit will convert a No. 2 into a No. 3 Outfit. See page 41



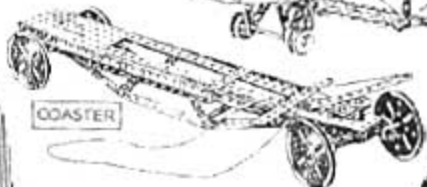
CARRIER TRICYCLE



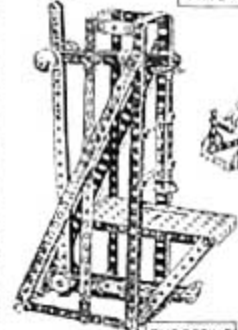
TRAVELING JIB CRANE



AEROPLANE



COASTER



EMBOSSING MACHINE



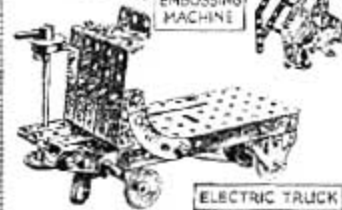
RAILWAY BRIDGE WITH SIGNALS



HIGH-LEVEL BRIDGE



PIT-HEAD GEAR



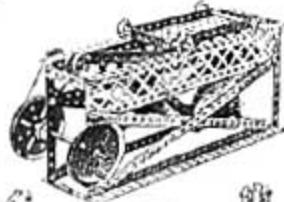
ELECTRIC TRUCK



CANDY PULLER



WINDMILL



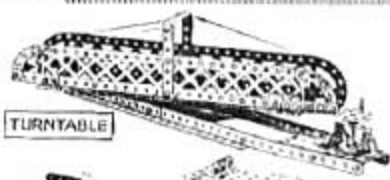
SIFTER



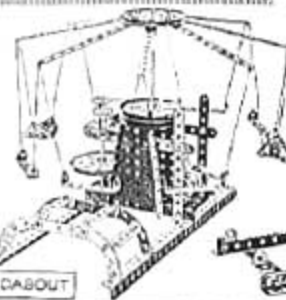
STEAM LORRY



FIRE ESCAPE



TURNTABLE



ROUNDABOUT



ANTI-AIRCRAFT GUN



STAMPING MILL



MAT FRAME



HAY TEDDER



TRY-YOUR-STRENGTH MACHINE

MECCANO BOYS BUILD AND INVENT

MECCANO

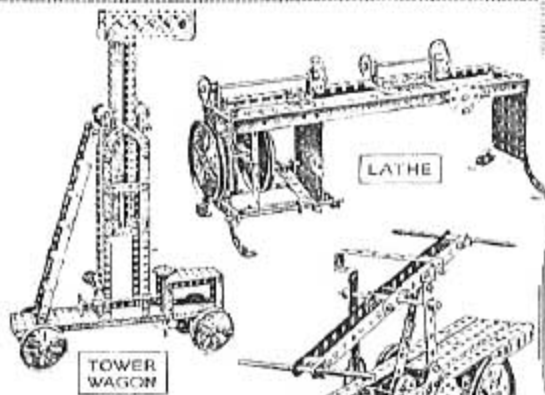


No. 3 Outfit

This excellent Outfit contains many advanced engineering parts and the models that may be constructed are of a better type, as will be seen from the examples illustrated on this page. A Manual of Instructions showing how to build 447 models is included.

Price 27'6

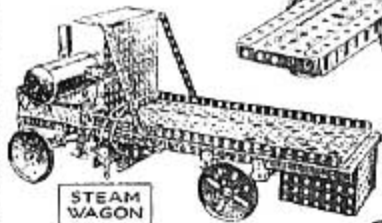
A No. 3a Accessory Outfit will convert a No. 3 into a No. 4 Outfit. See page 43



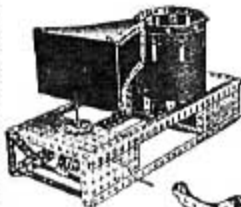
TOWER WAGON

LATHE

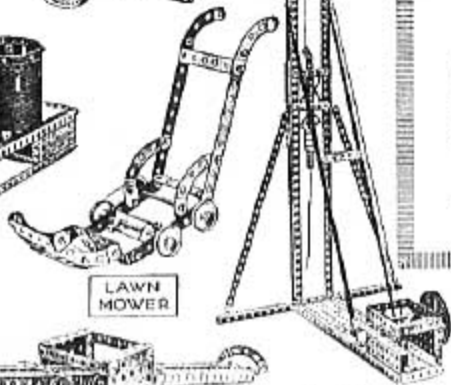
HAND TROLLEY



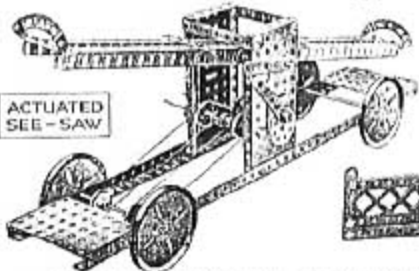
STEAM WAGON



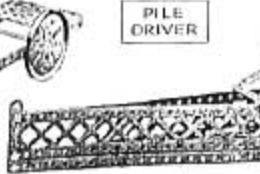
KINETOGRAPH



LAWN MOWER



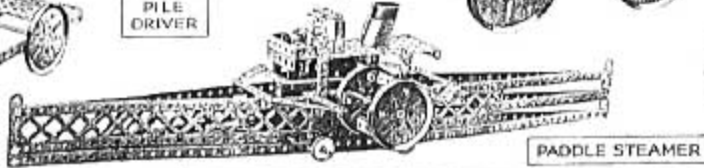
ACTUATED SEE-SAW



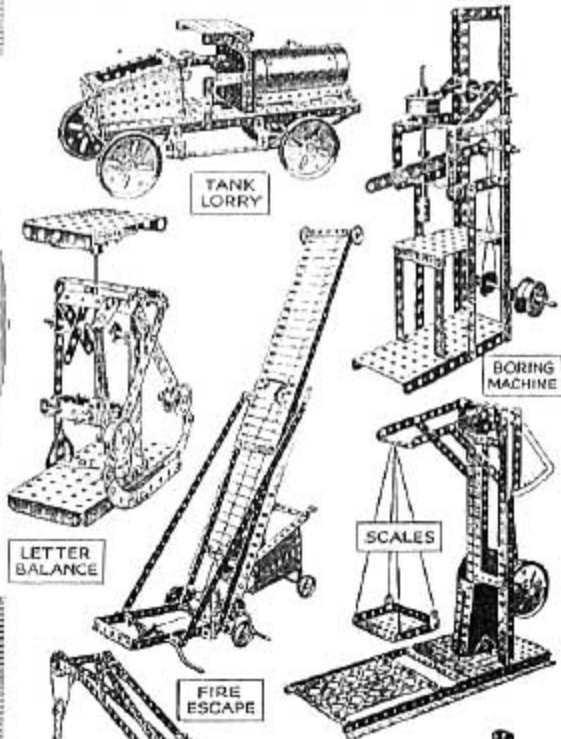
PILE DRIVER



TANK WAGON



PADDLE STEAMER



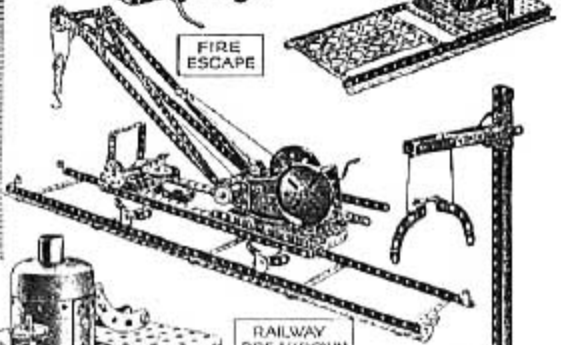
TANK LORRY

LETTER BALANCE

FIRE ESCAPE

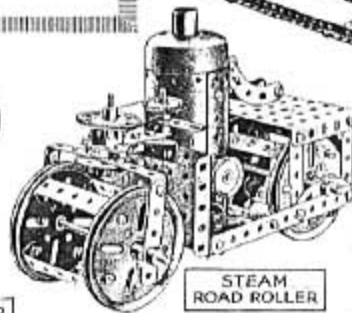
BORING MACHINE

SCALES



RAILWAY BREAKDOWN CRANE

RAILWAY GAUGE



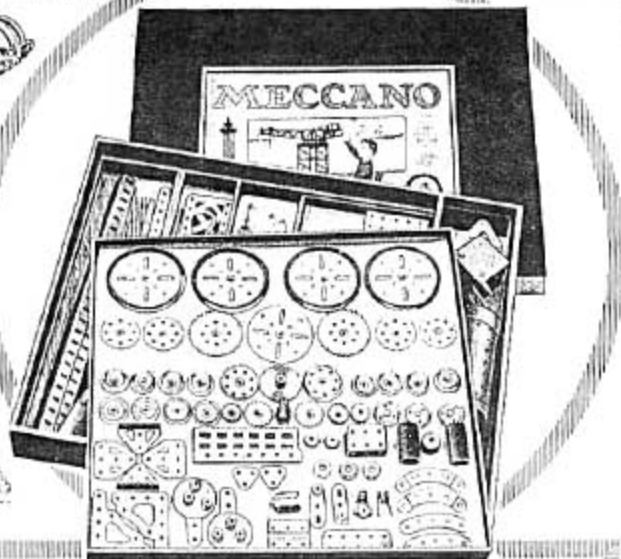
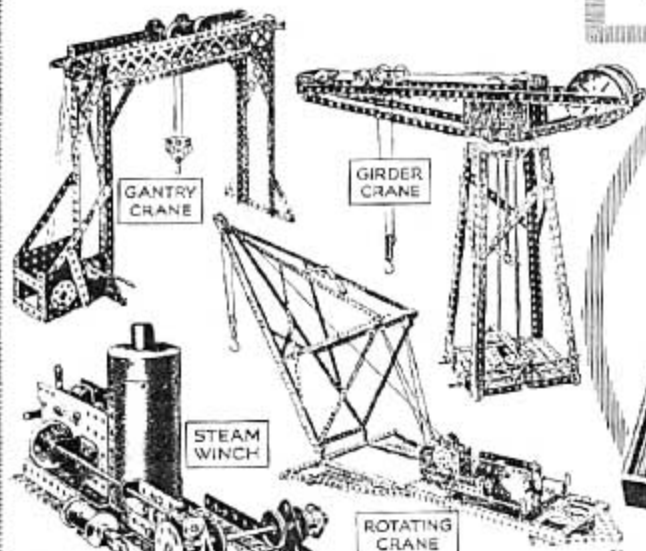
STEAM ROAD ROLLER



TOBOGGAN

THE FINEST HOBBY IN THE WORLD

MECCANO

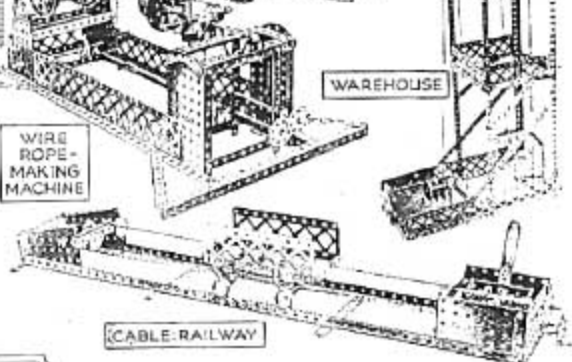
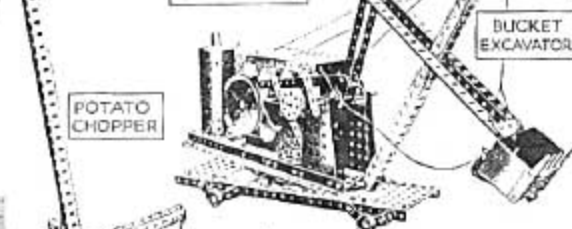
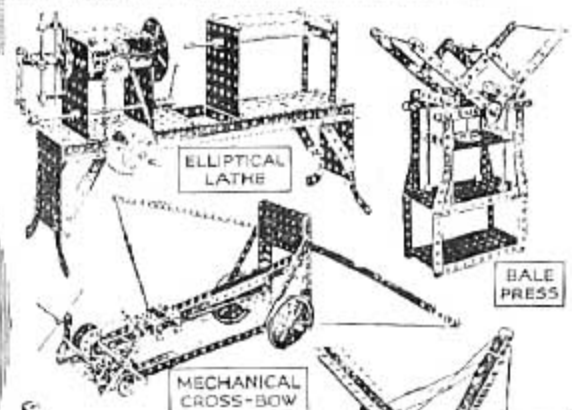
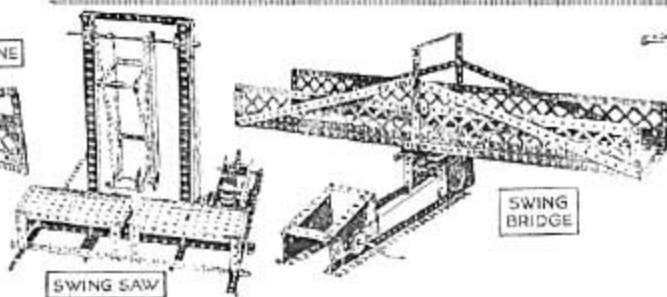
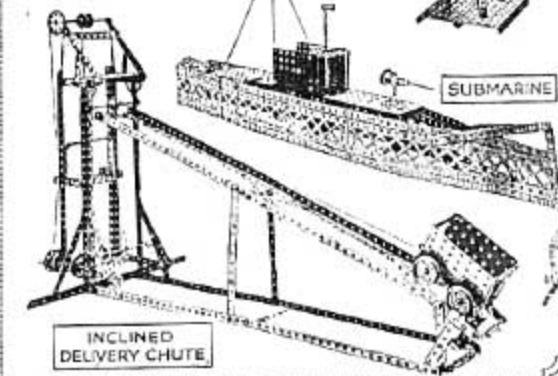
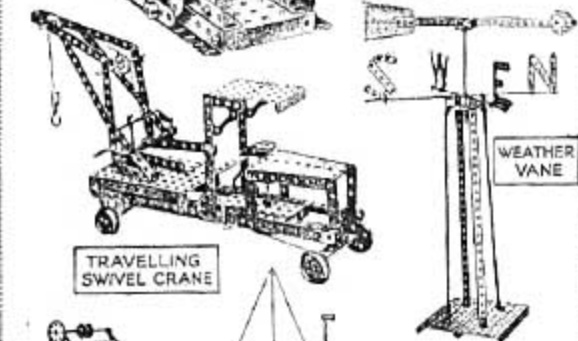


No. 4 Outfit

This fine Outfit contains a splendid range of Meccano parts with which an excellent variety of superb models may be built. The Manuals of Instructions that are included give examples of 504 models that may be constructed, and a selection of these is illustrated on this page.

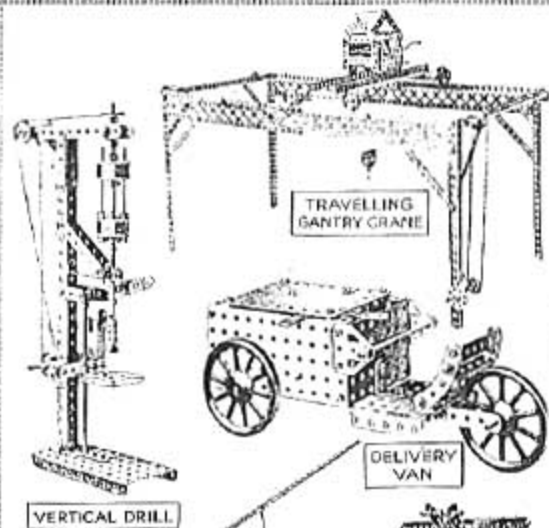
Price 50/-

A No. 4a Accessory Outfit will convert a No. 4 into a No. 3 Outfit. See page 41.



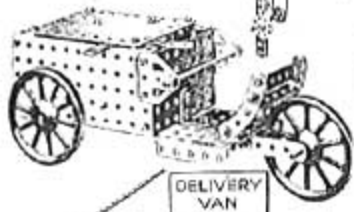
THE PIONEER CONSTRUCTION TOY

MECCANO

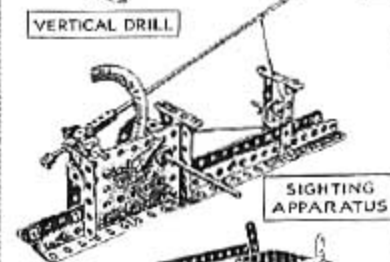


VERTICAL DRILL

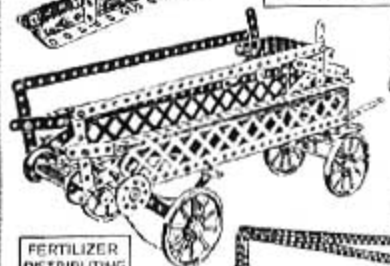
TRAVELLING GANTRY CRANE



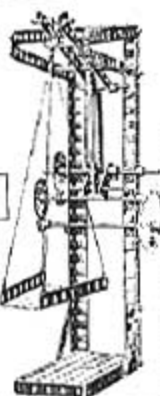
DELIVERY VAN



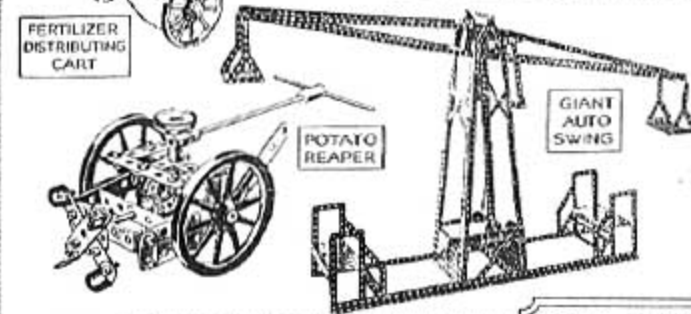
SIGHTING APPARATUS



FERTILIZER DISTRIBUTING CART

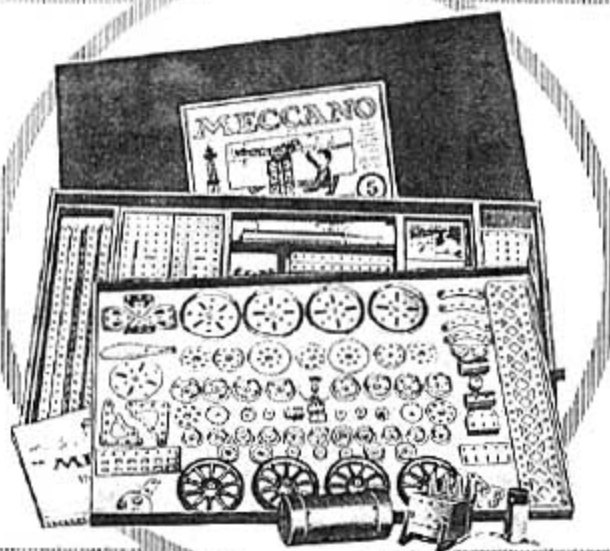


SPRING SCALES



POTATO REAPER

GIANT AUTO SWING



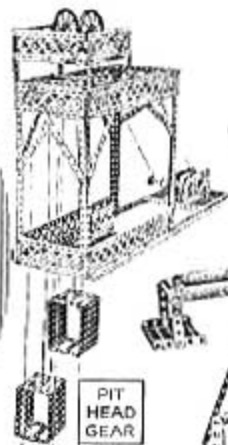
No. 5 Outfit

No. 5 Outfit is supplied either in a stout carton or in a handsome oak cabinet. The fine examples of real engineering models illustrated on this page are reproduced from the Manuals (included in the Outfit), which give examples of 547 models that may be built.

Price (packed in strong carton) ... 65/-

Price (packed in superior oak cabinet, fitted with lock and key) ... 95/-

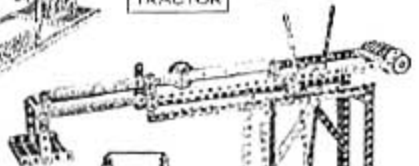
A No. 5A Accessory Outfit (carton or oak cabinet) will convert a No. 5 into a No. 6 Outfit. See page 11



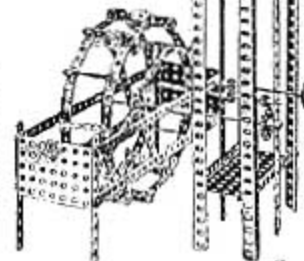
PIT HEAD GEAR



FARM TRACTOR



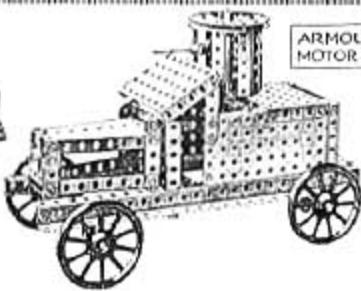
BEAM SCALES



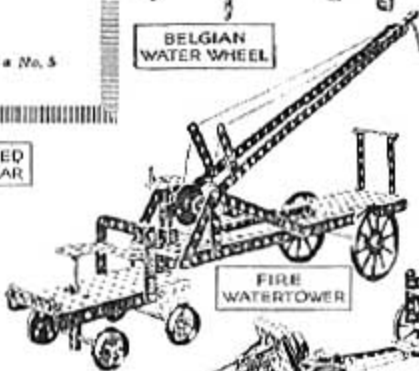
BELGIAN WATER WHEEL



FRET SAW



ARMOURED MOTOR CAR



FIRE WATERTOWER



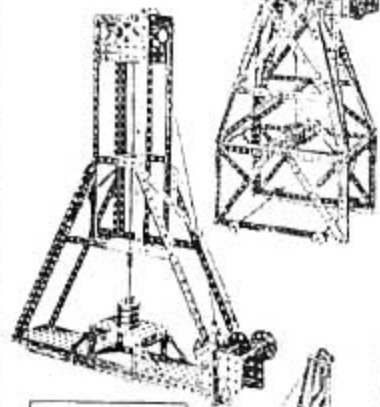
FIELD GUN & CARRIAGE

AN APPRENTICESHIP TO A CAREER

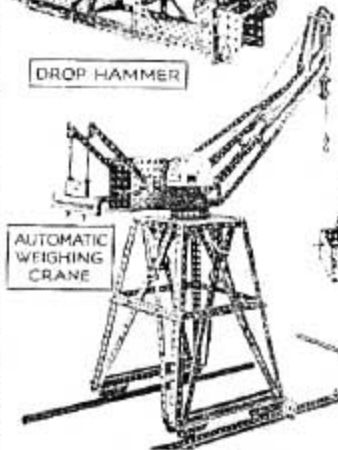
MECCANO



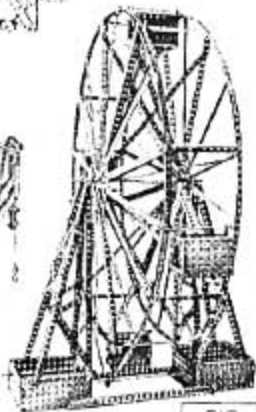
RADIAL TRAVELLING CRANE



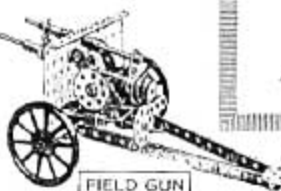
DROP HAMMER



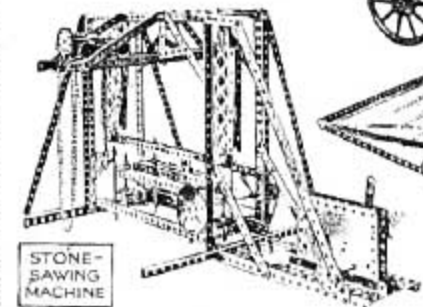
AUTOMATIC WEIGHING CRANE



BIG WHEEL



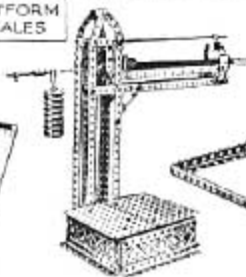
FIELD GUN



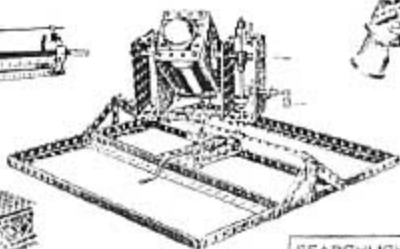
STONE-SAWING MACHINE



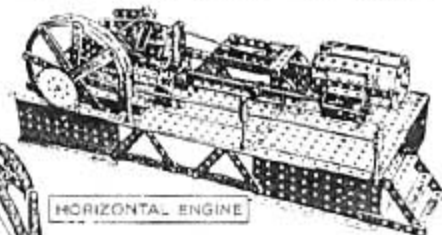
WEIGHBRIDGE



PLATFORM SCALES



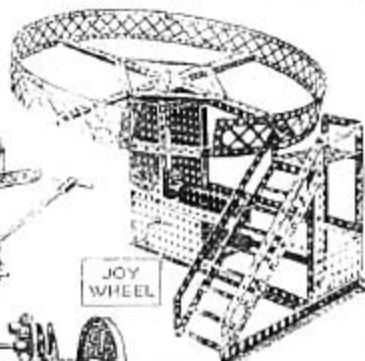
SEARCHLIGHT



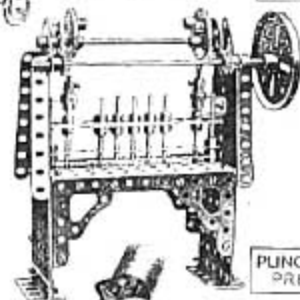
HORIZONTAL ENGINE



PORTABLE CRANE



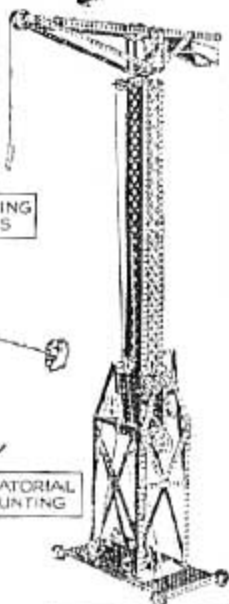
JOY WHEEL



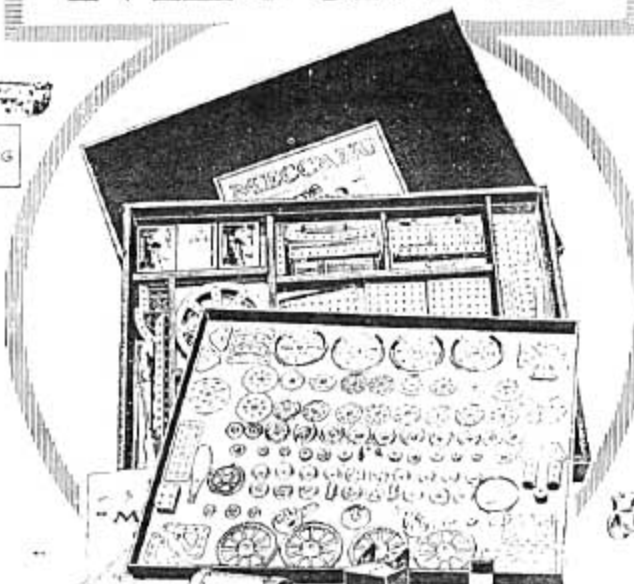
PUNCHING PRESS



EQUATORIAL MOUNTING



ELEVATED CRANE



No. 6 Outfit

No. 6 Outfit is supplied either in a stout carton or in a handsome oak cabinet. All the models of the earlier Outfits, and many more, may be constructed with this Outfit. The Manuals included show how to build 594 models, a few of which are illustrated on this page.

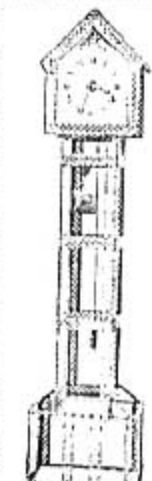
Price (packed in stout carton) ... 115/-

Price (packed in superior oak cabinet, fitted with lock and key) ... 150/-

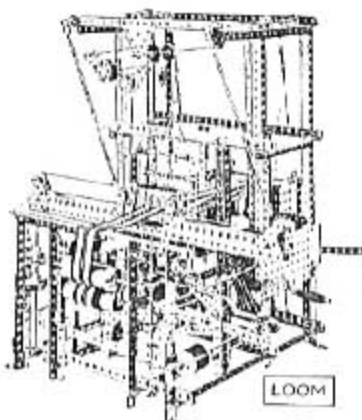
A No. 6x Accessory Outfit (with cabinet) will convert a No. 6 into a No. 7 Outfit. See page 41

THE WORLD'S MOST FAMOUS TOY

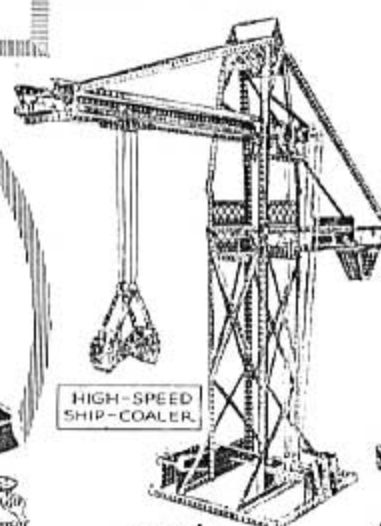
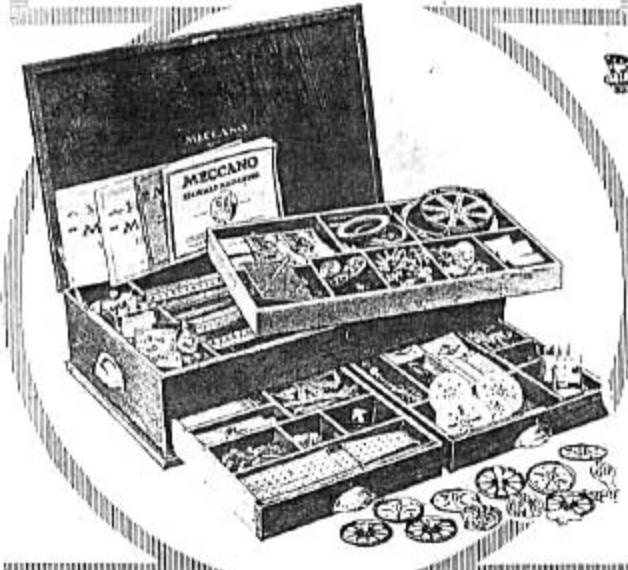
MECCANO



GRANDFATHER'S CLOCK



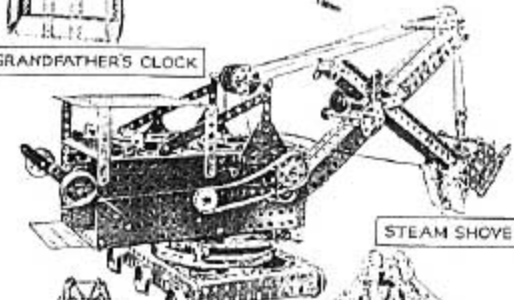
LOOM



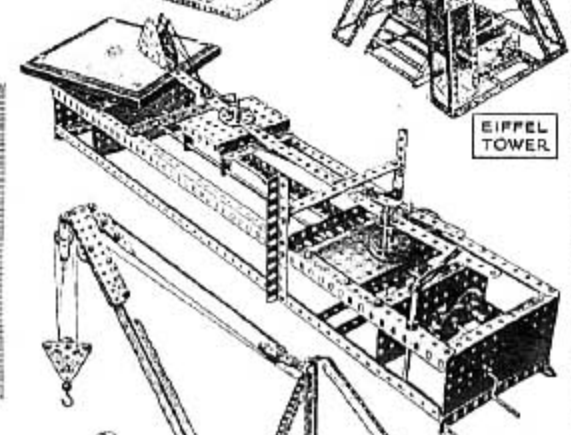
HIGH-SPEED SHIP-COALER



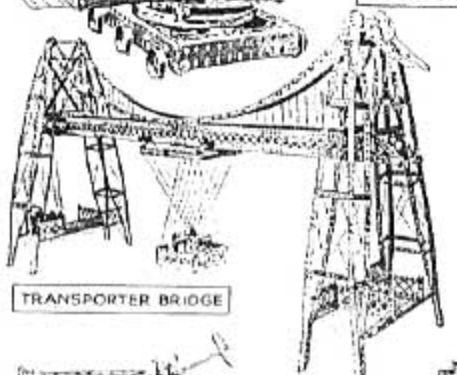
EIFFEL TOWER



STEAM SHOVEL



MECCANOGRAPH



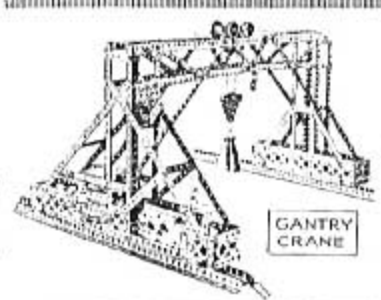
TRANSPORTER BRIDGE

No. 7 Outfit
 This is a complete and comprehensive Outfit, containing all Meccano parts, etc., necessary to build each of the models in all the Manuals of Instructions. A few examples of Meccano super models that may be built with No. 7 Outfit are illustrated on this page. An ideal present for a boy interested in mechanics or electricity.

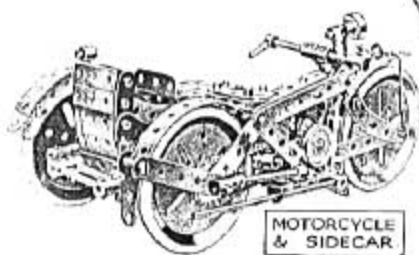
Price (packed in superior oak cabinet, fitted with lock and key) ... 380/-



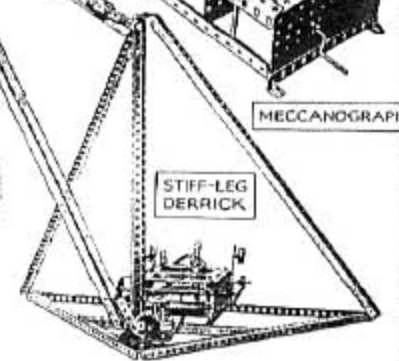
MOTOR CHASSIS



GANTRY CRANE



MOTORCYCLE & SIDECAR

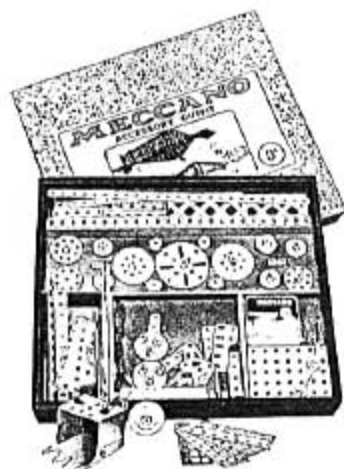


STIFF-LEG DERRICK

ENGINEERING IN MINIATURE

MECCANO

ACCESSORY OUTFITS AND STORAGE BOXES



No. 3a Accessory Outfit

The Purpose of Meccano Accessory Outfits

Meccano Accessory Outfits connect the main Outfits from No. 00 to No. 7. They may be aptly described as the stepping stones to bigger and better models. A No. 2 Outfit may be converted into a No. 3 by adding to it a No. 2a Accessory Outfit, and a No. 3a would then convert it into a No. 4. In this way, no matter with which Outfit a boy commences, he may build it up by degrees until he possesses all the parts contained in the largest Outfit.

The Meccano No. 3a Accessory Outfit is shown in the accompanying illustration.

Price List of Meccano Accessory Outfits

No. 00a (converts a No. 00 Outfit into a No. 0)	Price	1/6
" 0a (" " 0 " " " 1)	"	5/6
" 1a (" " 1 " " " 2)	"	7/-
" 2a (" " 2 " " " 3)	"	12/6
" 3a (" " 3 " " " 4)	"	23/6
" 4a (" " 4 " " " 5)	"	15/-
" 5a* (" " 5* " " " 6*)	"	50/-
" 5a† (" " 5† " " " 6†)	"	80/-
" 6a† (" " 6† " " " 7)	"	215/-

* Carton.
† Wood.



Special Inventor's Outfit

This Outfit makes a valuable addition to any keen model-builder's equipment. It is intended specially for boys who already have Meccano and who wish to satisfy their inventive inclinations by building models from their own designs. The parts contained include four large Pulley Wheels with Dunlop Tyres, Ball Race, Ship's Funnel, Pulley Blocks, Channel Bearing, Crane Grab, and many others.

Price 17/6

Storage Boxes for Meccano Parts

Almost every Meccano boy purchases additional Meccano parts from time to time, but he sometimes has difficulty in finding suitable accommodation for them. We are now pleased to announce that we can supply strongly-made boxes that have been specially designed for the purpose, enabling such extra parts to be stored neatly and methodically so that they are always easily accessible. There are three different sizes, each of which is illustrated and described below.

No. 1 Storage Box

Stained and varnished rich oak effect, and fitted with partitions as shown in the illustration. The lid is hinged and is secured by means of lock and key.

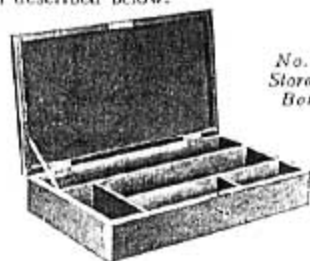
Price 10/6

Dimensions:

Length 15½ ins.

Width 8½ ins.

Depth 2½ ins.



No. 1 Storage Box

No. 2 Storage Box

Finished as No. 1 Box and provided with lock and key. The tray with which it is fitted enables a much larger quantity of parts to be accommodated.

Price 21/-

Dimensions: Length 14½ ins. Width 11 ins. Depth 3½ ins.



No. 2 Storage Box

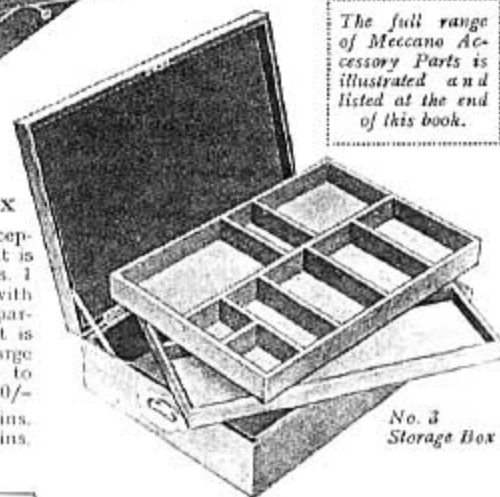
The full range of Meccano Accessory Parts is illustrated and listed at the end of this book.

No. 3 Storage Box

This box is a perfect receptacle for Meccano parts. It is finished similarly to the Nos. 1 and 2 Boxes and provided with lock and key. The two partitioned trays with which it is fitted enable a very large number of Meccano parts to be stored.

Price 30/-

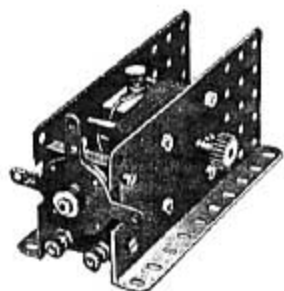
Dimensions: Length 20 ins. Width 14 ins. Depth 5½ ins.



No. 3 Storage Box

MECCANO BOYS BUILD AND INVENT

MECCANO MOTORS CLOCKWORK AND ELECTRIC



**Meccano
Electric
Motor No. 1**
(4 volt)

The 4-volt Motor is specially designed to build into Meccano models. It may be run by a 4-volt accumulator or, by employing the Transformer described below, from the main. It is fitted with reversing motion, provided with stopping and starting controls, and the gearing is interchangeable. 15/6

Important.—The 4-volt Motor will not run satisfactorily from dry cells.

Transformer

By means of this transformer the Meccano Electric Motor No. 1 (4 volt) may be driven from the house supply (alternating current only). It is available for all standard supply voltages, from 100 to 250 inclusive, at all standard frequencies. The supply voltage and frequency must be specified when ordering. Complete with length of flex and adapter for connection to an ordinary lamp socket. Price 30/-



Meccano Accumulators

These excellent accumulators have been specially adapted to drive the Meccano Electric Motor No. 1. 4 volt 8 amps. Price 17/6 4 volt 20 amps. Price 25/-

Meccano Resistance Controller

By employing this variable resistance the speed of the Meccano Electric Motor No. 1 (4 volt) may be regulated as desired. The controller is connected in series with the motor and accumulator, or with the motor and transformer if a transformer is used as the source of power. It will not regulate the speed of a high-voltage motor connected to the main. Price 3/6



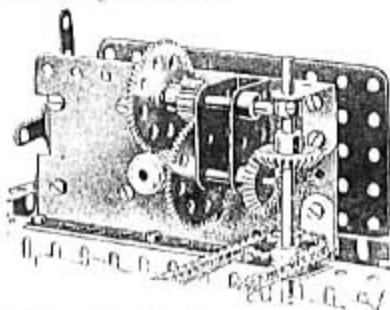
Run your Meccano Models with a Meccano Motor

If you wish to obtain the fullest possible enjoyment from the Meccano hobby you must operate your models with a Meccano motor. Just imagine the thrill of setting in motion your Crane, Ship-coaler, Motor Car, Windmill or any other model you build. You push over the control lever of the motor and immediately the model commences to work in exactly the same manner as its "big brother" in real life.

Meccano motors are strongly made and the utmost care is taken in their manufacture to ensure that they will give satisfaction to their owners. The side plates and bases are pierced with the standard Meccano equidistant holes, which enable the motors to be built into any Meccano model in the exact position required.

Various combinations of gears may be mounted on the motors for the purpose of reducing the speed of the driving spindles, and thereby increasing the lifting power. An instance of what is possible in this connection is shown by the illustration below.

All the motors have forward and reverse movements, a feature that greatly enhances the fun of running the models.

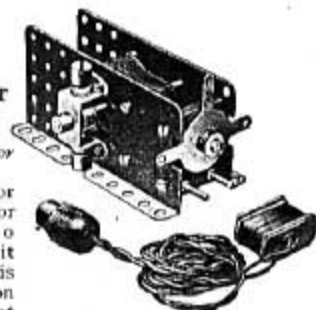


This illustration shows how easy it is to mount gearing on a Meccano Electric Motor. In this example the final shaft of the gear train rotates once in every 171 revolutions of the armature, thus providing a slow, powerful drive.

Meccano Electric Motor No. 2

(100-250 volt A.C. or D.C.)

This Electric Motor is specially adapted for driving Meccano models, into which it may be built. It is designed for connection with the electric light main—100-120 volts or 200-250 volts, alternating or direct. A 6 ft. length of flex, fitted with a plug for connection with the motor terminals and an adapter for connection with an ordinary lamp socket, is included. A suitable resistance is required when the motor is run with a 200-250-volt current, and this is supplied by connecting a 60-watt lamp in series with the motor. A board, on which are mounted a suitable lamp holder (lamp not included) and a switch, is provided separately. Price 32/6
Lamp board (with lamp holder and switch) .. 4/6



Meccano Rheostat

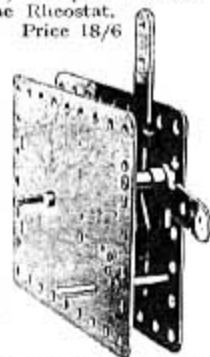
(For high voltage Motors)

This Rheostat is for controlling the speed of the Electric Motor No. 2 or the Hornby Metropolitan Train H.V. It may be connected to the house lighting system by means of an adapter and may be used with either alternating or direct currents ranging from 100 to 250 volts. A 60-watt lamp (not supplied) is required for use with the Rheostat. Price 18/6



Meccano Clockwork Motor

This is a splendid motor for driving Meccano models. It is fitted with starting, stopping and reversing levers, and all its movements are fully explained in the instructions that accompany it. Price 7/6



RUN YOUR MODELS WITH A MOTOR

MECCANO

MANUALS, OIL CANS, ENAMEL, ETC.



Meccano No. 4-7 Manual



Meccano Bound Manual



Meccano Standard Mechanisms Manual

The Meccano Manuals of Instructions

The Meccano Manuals are all beautifully printed and the illustrations are in half-tone throughout. Every Meccano boy should possess a copy of each of the 00-3 and 4-7 Manuals in which a total number of 626 models is illustrated, and also a copy of the Standard Mechanisms Manual in which a fine selection of real engineering movements that may be built with Meccano are reproduced. These Manuals may be purchased as separate units, or attractively bound in full cloth cover, lettered in gold.

The prices of the full range of Meccano Manuals are as follows:—

No. 0 Manual of Instructions	...	...	...	...	Price	4d.
No. 00-3	"	"	"	"	"	1/0
No. 4-7	"	"	"	"	"	1/6

Standard Mechanisms Manual	...	...	...	...	Price	1/-
Bound Manual of Instructions (comprising a 00-3 Manual, a 4-7 Manual and a Standard Mechanisms Manual)	...	...	...	...	"	7/6
Meccano Book of New Models	...	...	...	...	"	6d.



Meccano Lubricating Oil

Before commencing to operate a Meccano model, all gears and bearings should be oiled thoroughly with Meccano Lubricating Oil. This oil is specially prepared and is of the right consistency for the purpose.

Price, per bottle, 6d.



Oil Can No. 1

This is a miniature Oil Can that will give every satisfaction. It is strongly made and it functions perfectly.

Price 6d.



Oil Can No. 2 ("K" Type)

This miniature Oil Can operates perfectly. The oil is ejected drop by drop by depressing the valve.

Price 3/6

Meccano Enamel

The Meccano enamel has been introduced to enable model-builders to convert nickel parts to colour or to touch up coloured parts should such treatment become necessary through mishandling. It is available in red and green, each colour being identical in shade with the enamels used in the Meccano Factory for spraying Meccano parts.



Price, per tin, 8d.



Meccano Saw Bench

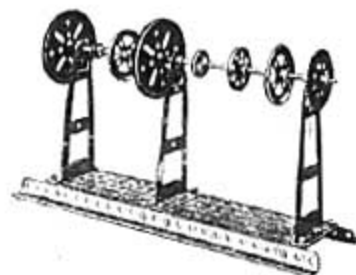
This model Saw Bench is suitable for use with an Electric or Clockwork Motor. By means of the equidistant holes in the base it may be built into a Meccano Model Workshop. Beautifully finished in black enamel and nickel.

Price 4/-

Meccano Shafting Standards

These Shafting Standards are designed on the Meccano system, with equidistant holes. Our illustration shows how strong and serviceable shafting may be constructed from Meccano parts with the aid of the Large Standard.

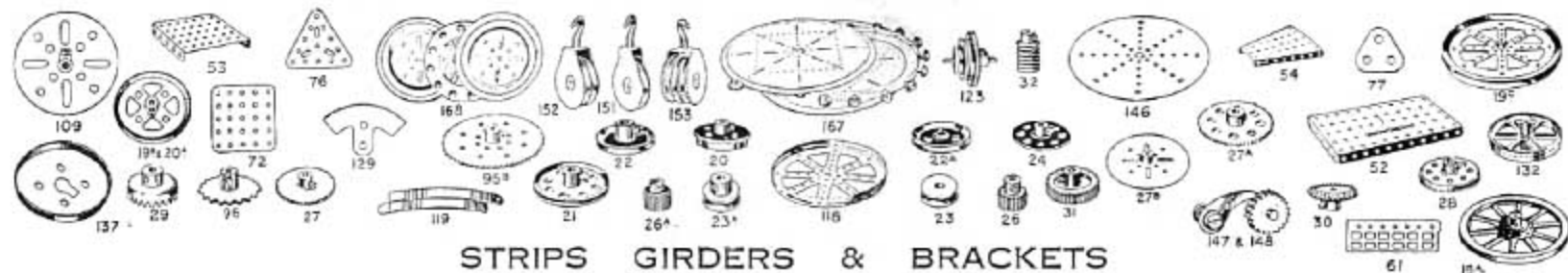
Standard only, Large ... Price 1/-
 " " Small ... " 8d.



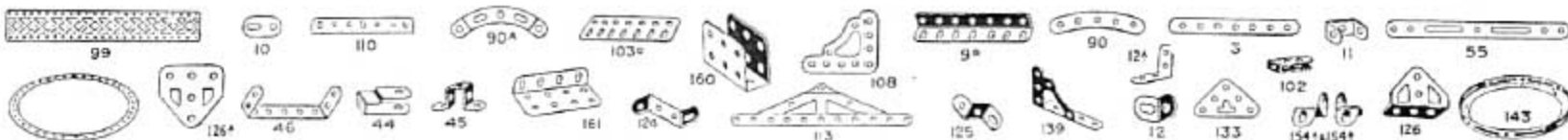
ENGINEERING FOR BOYS

MECCANO ACCESSORY PARTS

WHEELS - PULLEYS - GEARS - PLATES - ETC.



STRIPS GIRDERS & BRACKETS



No.	Description	Quantity	Unit
1.	Perforated Strips, 12 1/2" long	1	doz.
1a.	" " " "	1	doz.
1b.	" " " "	1	doz.
2.	" " " "	1	doz.
2a.	" " " "	1	doz.
3.	" " " "	1	doz.
4.	" " " "	1	doz.
5.	" " " "	1	doz.
6.	" " " "	1	doz.
6a.	" " " "	1	doz.
7.	Angle Girders, 2 1/2" long	1	each
7a.	" " " "	1	each
8.	" " " "	1	doz.
8a.	" " " "	1	doz.
8b.	" " " "	1	doz.
9.	" " " "	1	doz.
9a.	" " " "	1	doz.
9b.	" " " "	1	doz.
9c.	" " " "	1	doz.
9d.	" " " "	1	doz.
9e.	" " " "	1	doz.
9f.	" " " "	1	doz.
9g.	" " " "	1	doz.
10.	Flat Brackets	1	each
11.	Double Brackets	1	each
12.	Angle Brackets, 1 1/2" x 1 1/2"	1	doz.
12a.	" " " "	1	doz.
12b.	" " " "	1	doz.
13.	Axle Rods, 1 1/2" long	1	each
13a.	" " " "	1	each
14.	" " " "	1	each
15.	" " " "	1	each
15a.	" " " "	2	for
16.	" " " "	1	each

No.	Description	Quantity	Unit
16a.	Axle Rods, 2 1/2" long	2	for
16b.	" " " "	1	each
17.	" " " "	3	for
18.	" " " "	1	each
18a.	" " " "	1	each
19.	Crank Handles, Large	1	each
19a.	" " " Small	1	each
19b.	Wheels, 3" diam., with set screws	1	each
20.	Flanged Wheels, 1 1/2" diam.	1	each
20a.	" " " "	1	each
20b.	" " " "	1	each
20c.	" " " "	1	each
20d.	" " " "	1	each
20e.	" " " "	1	each
20f.	" " " "	1	each
20g.	" " " "	1	each
20h.	" " " "	1	each
20i.	" " " "	1	each
20j.	" " " "	1	each
20k.	" " " "	1	each
20l.	" " " "	1	each
20m.	" " " "	1	each
20n.	" " " "	1	each
20o.	" " " "	1	each
20p.	" " " "	1	each
20q.	" " " "	1	each
20r.	" " " "	1	each
20s.	" " " "	1	each
20t.	" " " "	1	each
20u.	" " " "	1	each
20v.	" " " "	1	each
20w.	" " " "	1	each
20x.	" " " "	1	each
20y.	" " " "	1	each
20z.	" " " "	1	each
21.	50 teeth to gear with 1" pinion	1	each
27a.	" " " "	1	each
27b.	" " " "	1	each
27c.	" " " "	1	each
28.	Contrae Wheels, 1 1/2" diam.	1	each
29.	" " " "	1	each
30.	Bevel Gears, 1/2", 28 teeth	1	each

No.	Description	Quantity	Unit
30a.	Bevel Gears, 1/2", 18 teeth	1	each
30b.	" " " "	1	each
31.	Gear Wheels, 1", 38 teeth	1	each
32.	Worm Wheels	1	each
*34.	Spanners	1	each
*34b.	Box Spanners	1	each
35.	Spring Clips	1	per box (10z.)
36.	Screw Drivers	1	each
*36a.	" " " " Extra Long	1	each
*36b.	" " " " Special	1	each
37.	Nuts and Bolts, 7/32"	1	per box (10z.)
37a.	" " " "	1	per box (10z.)
37b.	" " " "	1	per box (10z.)
*38.	Washers	1	each
40.	Hanks of Cord	2	for
41.	Propeller Blades	1	per pair
43.	Springs	1	each
*44.	Cranked Bent Strips	1	each
45.	Double	1	each
46.	Double Angle Strips, 2 1/2" x 1 1/2"	1	doz.
47.	" " " "	1	doz.
47a.	" " " "	1	doz.
48.	" " " "	1	doz.
48a.	" " " "	1	doz.
48b.	" " " "	1	doz.
48c.	" " " "	1	doz.
48d.	" " " "	1	doz.
48e.	" " " "	1	doz.
50.	Eye Pieces, with boss	1	each
52.	Perforated Flanged Plates, 5 1/2" x 2 1/2"	1	each
52a.	" " " "	1	each
53.	Perforated Flanged Plates, 3 1/2" x 2 1/2"	1	each
53a.	" " " "	1	each
54.	Perforated Flanged Sector Plates	1	each

No.	Description	Quantity	Unit
55.	Perforated Strips, slotted, 5 1/2" long	1	each
55a.	" " " "	1	each
56.	Instruction Manuals, No. 4-7	1	each
56a.	" " " " No. 00-3	1	each
56b.	" " " " No. 0	1	each
56c.	Meccano Standard Mechanisms Manual	1	each
56d.	" " " " Book of New Models	1	each
56e.	Bound Manual of Instructions	1	each
57.	Hooks	2	for
57a.	" " " " Scientific	1	each
57b.	" " " " Loaded	1	each
58.	Spring Cord	1	per length
59.	Collars with Set Screws	2	for
61.	Windmill Sails	4	for
62.	Cranks	1	each
62a.	Threaded Cranks	1	each
62b.	Double Arm Crank	1	each
63.	Couplings	1	each
63a.	Octagonal Couplings	1	each
63b.	Strip Couplings	1	each
64.	Threaded Bosses	1	each
65.	Centre Pucks	1	each
65.	Weights, 50 grammes	1	each
67.	" " " "	1	each
68.	Wood screws, 1/2"	1	doz.
69.	Set Screws	1	doz.
69a.	Grab Screws, 5/32"	1	doz.
69b.	" " " "	1	doz.
70.	Flat Plates, 5 1/2" x 2 1/2"	1	each
72.	" " " " 2 1/2" x 2 1/2"	1	each
70.	Triangular Plates, 2 1/2"	1	each
77.	" " " " 1"	1	each

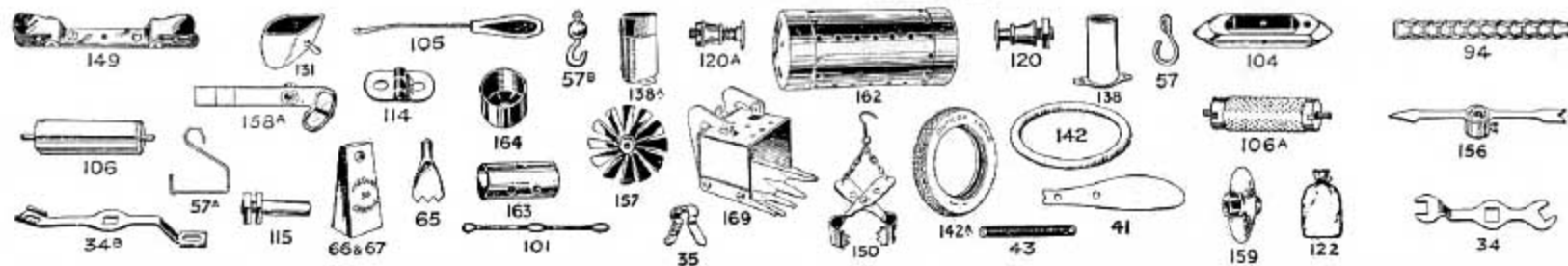
IMPORTANT.—Meccano Accessory Parts will be supplied in colours unless nickelled parts are specially ordered.
*These parts are available with nickel finish only.

MECCANO ACCESSORY PARTS

RODS - CRANKS - COUPLINGS - ETC.



MISCELLANEOUS



No.	Description	Quantity	Unit	Price
78.	Screwed Rods, 11 1/2" long	each	0 6	
79.	" " " 8"	"	0 8	
79a.	" " " 5"	"	0 4	
80.	" " " 5"	"	0 3	
80a.	" " " 3 1/2"	"	0 3	
80b.	" " " 4 1/2"	"	0 3	
81.	" " " 2"	"	0 2	
82.	" " " 1"	"	0 1	
80.	5 1/4" Curved Strips, 10" radius	"	0 2	
80a.	" " " cracked, 1 1/2" radius, 4 to circle	"	0 2	
50.	2 1/2" " " 2 1/2" radius	"	0 1	
50a.	2 1/2" " " cracked, 1 1/2" radius, 4 to circle	"	0 1	
91.	Sprocket Chain, per 40" length	0 8		
95.	Sprocket Wheels, 2" diam.	each	0 5	
95a.	" " " 1 1/2"	"	0 4	
95b.	" " " 1"	"	0 3	
95c.	" " " 3/4"	"	0 3	
97.	Bracket Girders, 3 1/2" long	1/2 doz.	0 9	
97a.	" " " 3"	"	0 8	
98.	" " " 1 1/2"	"	0 6	
99.	" " " 1 1/4"	"	0 6	
99a.	" " " 9/8"	"	0 6	
99b.	" " " 7/8"	"	0 6	
100.	" " " 3/4"	"	0 6	
100a.	" " " 4/8"	"	0 10	
101.	Heads for lugs	doz.	0 9	
102.	Single Heat Strips	each	0 1	
103.	Flat Girders, 5 1/2" long	1/2 doz.	0 10	
103a.	" " " 5"	"	1 2	
103b.	" " " 12 1/2"	"	1 3	

No.	Description	Quantity	Unit	Price
103c.	Flat Girders, 4 1/2" long	1/2 doz.	0 9	
103d.	" " " 3 1/2"	"	0 7	
103e.	" " " 3"	"	0 8	
103f.	" " " 2 1/2"	"	0 5	
103g.	" " " 2"	"	0 4	
103h.	" " " 1 1/2"	"	0 4	
103i.	" " " 7/8"	"	1 0	
104.	Shuttles, for looms	each	7 6	
105.	Rod Hooks, for looms	"	0 4	
106.	Wood Rollers	"	1 6	
106a.	Sand Rollers	"	1 6	
107.	Tables for Designing Machines	"	1 6	
108.	Architraves	"	0 2	
109.	Face Plates, 2 1/2" diam.	"	0 4	
110.	Rack Strips, 3 1/2"	"	0 2	
111.	Dolls, 1"	2 for	0 1	
111a.	" " " 3/4"	3 for	0 1	
111b.	" " " 1/2"	doz.	0 3	
112.	" " " 1/4"	each	0 2	
113.	Ginler Frames	each	0 9	
114.	Hinges	per pair	0 4	
115.	Threaded Pins	each	0 2	
116.	Pork Pieces, Large	"	0 3	
116a.	" " " Small	"	0 3	
117.	Steel Balls, 1/2" diam.	doz.	0 1	
118.	Hub Discs, 5/4" diam.	each	1 3	
119.	Channel Segments (8 to circle, 1 1/4" diam.)	"	0 4	
120.	Butlers	"	0 2	
120a.	Spring Butlers	per pair	0 8	
120b.	Compression Springs	each	0 1	
121.	Train Couplings	"	0 2	
122.	Miniature Loaded Sacks	"	0 2	
123.	Cone Pulleys	"	1 3	

No.	Description	Quantity	Unit	Price
124.	Reversed Angle Brackets, 1"	1/2 doz.	0 3	
125.	" " " 1 1/2"	"	0 3	
126.	Trunnions	each	0 2	
126a.	Flat Trunnions	"	0 1	
127.	Simple Bell Cranks	"	0 1	
128.	Doss Bell Cranks	"	0 3	
129.	Rack Segments, 3" diam.	"	0 5	
130.	Triple Throw Eccentrics	"	1 0	
131.	Dragger Buckets	1/2 doz.	1 0	
132.	Flywheels, 2 1/2" diam.	each	2 0	
133.	Corner Brackets	"	0 1	
134.	Crank Shafts, 1" stroke	"	0 2	
135.	Theodolite Projectors	"	0 3	
136.	Handrail Supports	"	0 3	
137.	Wheel Flanges	"	0 3	
138.	Ship's Funnels	"	0 3	
138a.	" " " Curved type	"	0 3	
139.	Flanged Brackets (right)	"	0 2	
139a.	" " " (left)	"	0 2	
140.	Universal Couplings	"	0 10	
141.	Wire Lines (for suspending clock weights)	"	0 9	
142.	Rubber Rings, 3" rim	"	0 3	
142a.	Dunlop Tyre to fit 2" diam. rim	"	0 4	
142b.	" " " 3"	"	0 5	
143.	Circular Girders, 5/4" diam.	"	1 0	
144.	Dog Clutches	"	0 6	
145.	Circular Straps, 7" diam. over all	"	0 9	
146.	Plates, 6"	"	1 0	
147.	Pawls, with pivot bolts and nuts	"	0 3	
147a.	Pawls	"	0 2	
147b.	Pivot Bolt with 2 nuts	"	0 2	
148.	Ratchet Wheels	"	0 8	

No.	Description	Quantity	Unit	Price
149.	Collecting Shoes, for Electric Locomotives	each	1 6	
150.	Crane Grabs	"	0 7	
151.	Pulley Blocks, Single Sheave	"	0 8	
152.	" " " Two	"	0 9	
153.	" " " Three	"	1 0	
154a.	Corner Angle Brackets, 1", right hand	1/2 doz.	0 6	
154b.	Corner Angle Brackets, 1", left hand	"	0 6	
155.	Roller Rings, 1"	each	0 1	
156.	Pinions, 2 1/2" diam. over all, with boss	"	0 4	
157.	Pins, 2" diam.	"	0 4	
158a.	Signal Arms, Home	"	0 5	
158b.	" " " Distant	"	0 5	
159.	Circular Saws	"	1 0	
160.	Channel Bearings, 1 1/4" x 1" x 1/4"	"	0 2	
161.	Ginler Bracket, 2" x 1" x 1"	2 for	0 3	
162.	Boiler, complete with ends	each	1 0	
162a.	Boiler ends	"	0 3	
163.	Sleeve Pieces	pair	0 9	
164.	Chimney Adaptors	each	0 2	
165.	Swivel Bearings	"	0 6	
166.	Eyeb	"	0 3	
167.	Geared Roller Bearings	"	29 0	
167a.	Roller Races, geared, 192 teeth	"	4 6	
167b.	Roller Races, geared, 192 teeth	"	3 0	
167c.	Pinions for Roller Bearings, 16 teeth	"	1 0	
168.	Ball Bearings, 4" diam.	"	3 0	
168a.	Ball Races, flanged	"	0 6	
168b.	" " " geared	"	0 6	
168c.	Ball Casings, complete with balls	"	1 0	
169.	Digger Buckets	"	2 0	
170.	Eccentric, 1/4" throw	"	0 0	

IMPORTANT.—Meccano Accessory Parts will be supplied in colours unless nichelled parts are specially ordered.
*These parts are available with nichel finish only.



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