British Marine Engine History in Meccano

I.—Symington and Bell Lead the Way

THERE are few subjects of greater interest than marine engineering, for without reliable and efficient ships' engines, commerce on the world-wide scale of the present day would be impossible. Great Britain is particularly dependent on steamship services, for the greater part of her foodstuffs and raw materials for her industries are imported and in return she exports coal and manufactured goods to all parts of the world. It is scarcely surprising, therefore, to find that British engineers have played a great part in the development of the modern steam vessel.

The story of the growth of the marine engine from that installed in a small boat in 1786 by William Symington, the pioneer of marine engines in this country, to the great quadruple expansion engines and steam turbines of the present day, is one of the romances of engineering. In this series of articles this growth will be followed with the aid of Meccano models, each of which illustrates an important advance in marine engineering. The models will not only show the first engine ever employed in a British ship, but also will demonstrate how successive changes have led to the development of the powerful modern engines that drive immense vessels at high speed and yet are economical in regard to fuel consumption.

As already indicated, the first successful application of steam to a British vessel was due to William Symington, who in 1786 took out a patent for this method of propulsion. Symington was a mining engineer who fitted an engine to a boat owned by Patrick Miller, a retired Edinburgh banker, and in 1788 the vessel was tried with success on a lake owned by Miller at Dalswinton, near Dumfries.

Although the details of Miller's boat have been lost, Symington's engine is preserved in the South Kensington Museum, London, and forms the subject of the model shown in Fig. 1. Each of the two cylinders is built up from four 3½" Strips and they are mounted 2½" apart on top of the condenser that is constructed from two 5½"×2½" Flanged Plates coupled together, in the form of a shallow box, by means of four Flat Brackets.

The piston rods are attached at their outer ends to crossheads working in slides fitted outside the main framework of the engine. One end of a length of cord is secured to each piston rod, and the cords pass in opposite directions round two large Flanged Wheels situated between the two piston rods. The cords are then attached to lengths of Sprocket Chain, one end of each being coupled to a pawl and ratchet mechanism. In this manner the two pistons, working alternatively, operate the paddle wheels, the rotation of which is made continuous by connecting them together by means of Sprocket Chain.

The valves are operated from a vertical tappet rod, the lower end of which is weighted and the four tappets consist of ⅜" Bolts carried in Collars. It should be noted that the inlet valve of one cylinder is coupled to the exhaust valve of the opposite cylinder by 2½" Strips and Flat Brackets. The piston rods pass through the condenser and their lower ends are raised and lowered alternatively by means of a 2½" Strip pivoted about its centre and actuated by a Crank on the far side of the model.

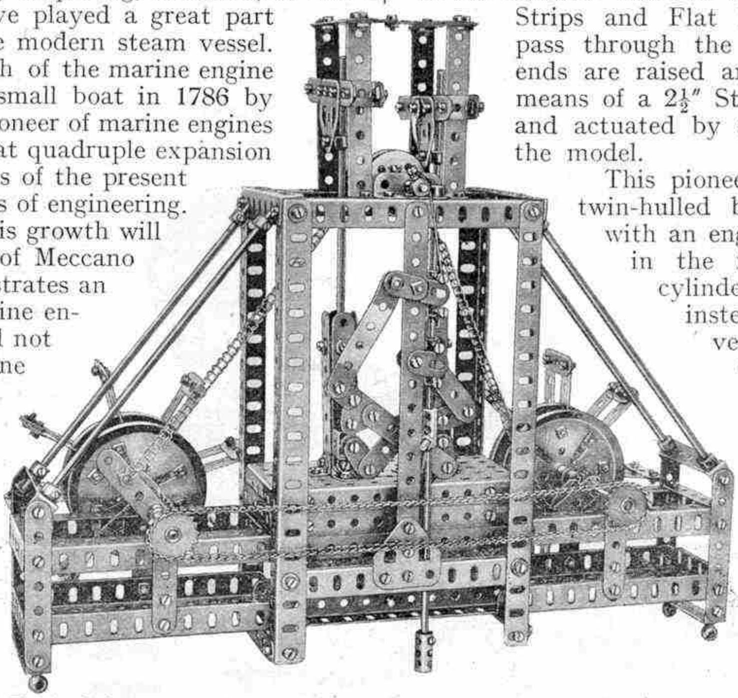

Fig. 1. A fine model of Symington's original Marine Engine, built with Outfit No. 6.

This pioneer vessel was followed by a twin-hulled boat 60 ft. in length fitted with an engine similar to that installed in the first boat except that its cylinders were 18" in diameter instead of 4" as in the earlier vessel. A speed of 7 m.p.h. was attained in trials on the Forth and Clyde Canal but in spite of this success Miller for some reason or other became dissatisfied and abandoned the experiments. Symington persevered, however, but although he continually attempted to interest influential people in his designs he made no progress until ten years later, when Lord Dundas commissioned him to build a steam boat suitable for towing barges along the Forth and Clyde Canal. The commission was accepted and the result was the first successful steam tug in the world.

The "*Charlotte Dundas*," as this boat was named, was commenced in 1801 and her first trip was made early in 1802. After a few preliminary experiments a practical trial was made in March of that year when two well-laden barges, each of 70 tons burden, were towed against a strong head wind at a speed of over 3 m.p.h. for a distance of nearly 20 miles. Strong complaints were made by the directors of the canal in regard to damage done to the banks by the wash from the vessel, and Lord Dundas was compelled to abandon the enterprise. The "*Charlotte Dundas*" was withdrawn and placed in a lock at the side of the canal, where she remained until she fell to pieces.

This interesting vessel was 56 ft. in length with a beam of 18 ft. She was fitted with a stern paddle wheel driven by a direct-acting horizontal engine, the first of this type ever built, the cylinder of which had a diameter of 22 in. and a stroke of 4 ft. The boiler, the design of which played a great part in the success of the vessel, had an internal furnace, a practice that was not generally followed until many years after the death of Symington.

The appearance of the engine of the "*Charlotte Dundas*" is well represented in the model illustrated in Fig. 2. As will be seen from this, the engines in many modern factories are of the same type. The crosshead of the original engine consisted of two rollers, each working on a separate rail; and each side of the crosshead frame carried two levers connected by vertical levers to air pumps that were used for emptying the condenser of water and air. The piston rod was coupled by a long connecting rod to a crank mounted directly on to the paddle shaft. These and other features are reproduced in the model, except that the paddle wheel is shown fitted with four floats in order to keep the model within a No. 4 Outfit, although actually eight floats were used.

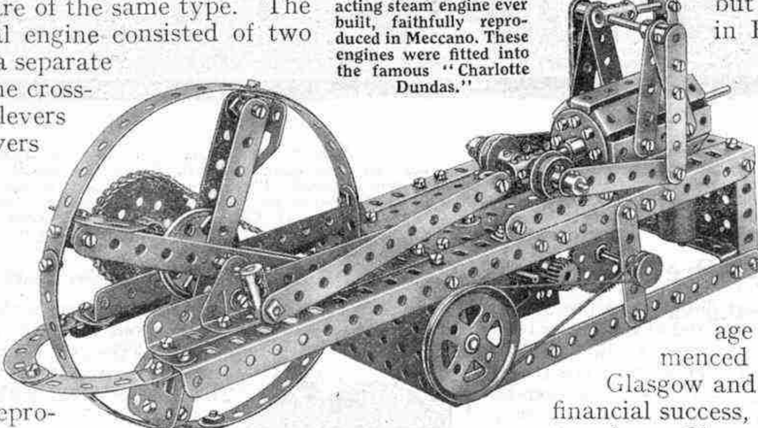

Fig. 2. The first direct acting steam engine ever built, faithfully reproduced in Meccano. These engines were fitted into the famous "Charlotte Dundas."

In the model the deck is represented by two $12\frac{1}{2}''$ Angle Girders joined together at one end by $3\frac{1}{2}'' \times 2\frac{1}{2}''$ Flanged Plates. The frame so formed is raised on two $3\frac{1}{2}'' \times 2\frac{1}{2}''$ Flanged Plates, these being braced together by $5\frac{1}{2}''$ and $2\frac{1}{2}''$ Strips, as shown in the illustration. The paddle wheel bearings are represented by two Trunnions bolted to $5\frac{1}{2}''$ Angle Girders that in turn are secured by Flat Brackets to the sides of the fork formed by the deck girders.

The cylinder is built up from two Bush Wheels and eight $2\frac{1}{2}'' \times \frac{1}{2}''$ Double Angle Strips and is bolted to the deck by two $\frac{3}{8}''$ Bolts, on each of which two Washers are placed between the deck and the cylinder for spacing purposes. The piston rod is fitted with a Coupling that carries two small Flanged Wheels, forming the crosshead, and these roll on two $2\frac{1}{2}''$ Strips attached to the deck by $\frac{1}{2}'' \times \frac{1}{2}''$ Angle Brackets. The ends of the rod carrying the Flanged Wheels are fitted with 3″ Strips, and these Strips are attached by Cranks to a horizontal Rod mounted above the cylinder. A Coupling on this Rod carries a second short Rod fitted with a Swivel Bearing that is attached to the vertical valve rod. The lower end of the valve rod is journalled in a Chimney Adaptor, mounted in a Sleeve Piece fitted beneath the deck plate.

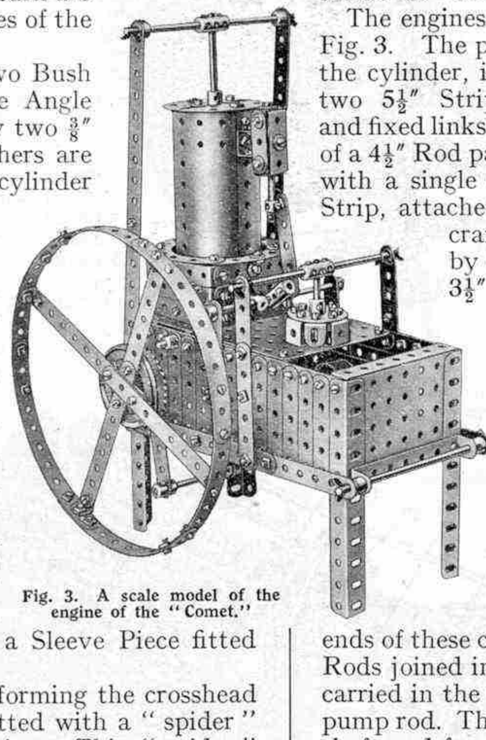

Fig. 3. A scale model of the engine of the "Comet."

The outer end of the Coupling, forming the crosshead support, carries a Threaded Pin fitted with a "spider" formed of part of a Swivel Bearing. This "spider" carries the connecting rod, the free end of which is attached by means of a Pivot Bolt to a Coupling, forming the crank.

The model is driven by means of an E1 Electric Motor, the drive from which is transmitted through a suitable gear train, a cord belt, and finally a belt of Sprocket Chain to a 2″ Sprocket Wheel on the paddle shaft.

The "*Charlotte Dundas*" was Symington's last attempt at steam navigation, for the expense of building the vessel and carrying out her trials reduced him to abject poverty. He died a few years later.

The next experiment of importance were made 22 years later by Henry Bell of Helensburgh. Bell was originally a carpenter in Glasgow, but after opening a boarding house in Helensburgh, a seaside resort on the Firth of Clyde, he conceived the idea of building a steam boat to bring passengers from Glasgow. The result was the "*Comet*," a vessel 40 ft. in length on the keel, and $10\frac{1}{2}$ ft. in beam. She made her first trip from Glasgow to Greenock in January, 1812, at an average speed of 5 m.p.h. Bell commenced a regular service between Glasgow and Greenock, but this was not a financial success, largely because the "*Comet*" was too slow. She was the first commercial steam vessel to be introduced, not only in Great Britain, but also in Europe, and her appearance began a new era in ship propulsion.

Naturally the sailing boat owners on the Clyde were greatly disturbed by the success of the "*Comet*." One skipper who greatly disliked the new vessel is said to have greeted her approach by ordering his crew, which consisted of one man and a boy, to "Kneel down and thank God that ye sail wi' A'michty's ain win', an' no' wi' the deevil's sulfire an' brimstane, like that spluttery thing there!"

The engines of this vessel are shown in model form in Fig. 3. The piston rod, which protrudes from the top of the cylinder, is coupled to two side levers by means of two $5\frac{1}{2}''$ Strips joined to represent connecting rods, and fixed links passing below these are connected by means of a $4\frac{1}{2}''$ Rod passing under the model. This Rod is fitted with a single short connecting rod, consisting of a $3\frac{1}{2}''$ Strip, attached at its upper end to a crankshaft. The crank consists of two Couplings joined together by a 1″ Rod and is fitted at each side with a $3\frac{1}{2}''$ Rod. The outer ends of these two Rods are journalled in the sides of the model. A $2\frac{1}{2}:1$ Sprocket Chain drive and a $9:1$ gear train connect this crankshaft with an E1 Electric Motor concealed within the box-like portion of the model representing the condenser. The steam valve is operated through a series of levers and cranks from a cam on the cran shaft. The air pump, mounted on the condenser, is actuated by two short connecting rods attached to the side levers at a point $3\frac{1}{2}''$ from their pivots. The upper ends of these connecting rods are secured together by two Rods joined in the centre by a Coupling and a short rod carried in the centre hole of this Coupling represents the pump rod. The flywheel is fitted to one side of the crankshaft and forms one of the most conspicuous features of the engine. The rim, which consists of six $5\frac{1}{2}''$ Strips each overlapping its neighbour three holes, is secured to the boss, a 2″ Pulley Wheel, by means of four $4\frac{1}{2}''$ Strips.

When the actual boat was first built it was fitted with four paddles and a large spur gear, of almost the same diameter as the flywheel, also was fitted. This engine developed about 3 h.p., and no doubt would have done better if the boiler had been more efficient.

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II.—The Paddle Wheel Era

LAST month some of the early British experiments with steam-propelled vessels were described, the last being Henry Bell's vessel, the "*Comet*," of 1812. The "*Comet*" did not meet with much public enthusiasm, and it was only with difficulty that she was made to pay for her upkeep, although, as an advertisement put it, "the elegance, safety, comfort and speed of this vessel require only to be seen to meet the approbation of the public."

The limited success of the "*Comet*" did not deter others from attempting to commercialise steam passenger boats, however, and the following 10 years saw many small vessels brought into service on the Clyde and elsewhere. Of these the "*Argyle*," subsequently the "*Thames*," appears to have been the most successful. She was a packet steamer of 70 tons, measuring 79 ft. on the keel and 16 ft. in beam, with paddle wheels 9 ft. in diameter and engines of 14 h.p. Her smoke was carried away by a funnel that acted also as a mast, being rigged with a large square sail. She had a gallery, on which the cabin windows opened, that projected to form a continuous deck except where broken by the paddle boxes, and on the outside of this gallery were painted 18 large portholes which, with two on her stern, gave her a very striking appearance. After plying for about 12 months between Glasgow and Greenock the "*Argyle*" was sold to a London firm who renamed her the "*Thames*." The voyage of this small ship from the Clyde to the Thames was a very remarkable one. Almost throughout the trip the weather was very wild, and it was only the skill and determination of Captain Dodd, an ex-Naval officer, that brought her safely through. It is interesting to note that when the "*Thames*" was off Wexford the smoke from her funnel led the local pilots to believe that she was on fire, and they put off to her assistance. Their surprise was great when they found the true state of affairs!

With reference to this vessel "*The Times*" of 8th July, 1815, said: "The *Thames*, steam yacht, from London to Margate, starts from Wool Quay, near the Custom House, Thames Street, every Tuesday and Saturday at 8 o'clock a.m. precisely, and leaves Margate on her return to London every Monday and Thursday at the same hour. . . . She has the peculiar advantage of proceeding either by sails or steam, separated or united, by which means the public have the pleasing certainty of never being detained on the water after dark, much less one or two nights, which has frequently occurred with the old packets. Against the wind, the tide, or in the most perfect calm, the passage is alike certain, and has always been achieved in one day."

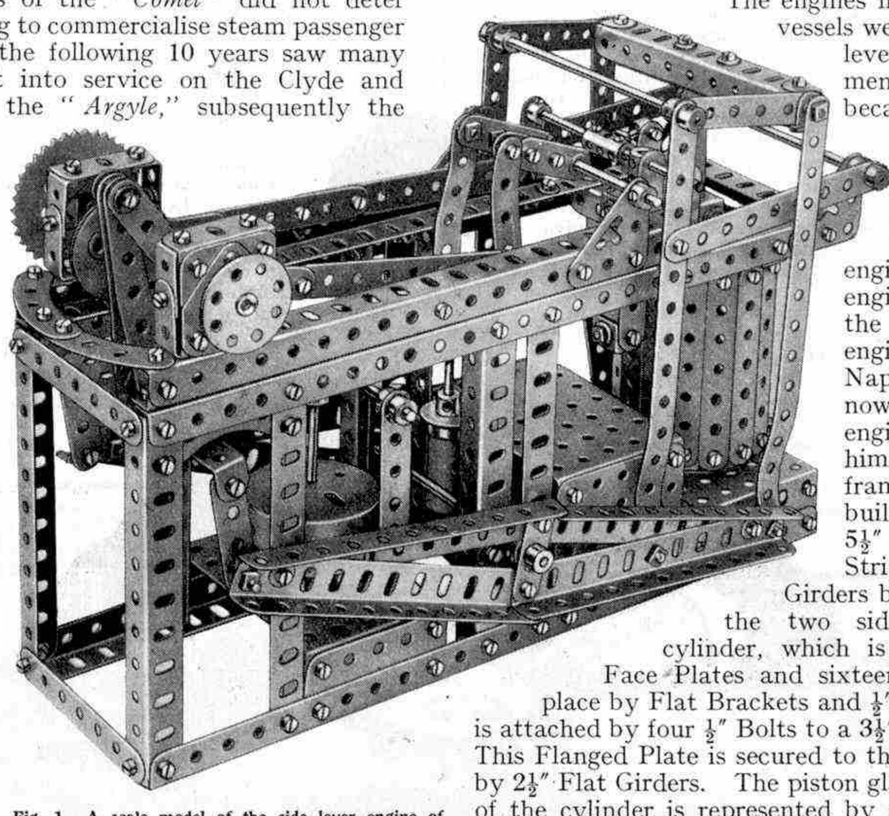

Fig. 1. A scale model of the side lever engine of the steamship "Leven," described in this article.

The engines fitted into these early vessels were usually of the side lever type, this arrangement being necessitated because of the lack of vertical space under the deck of these early vessels. Fig. 1 illustrates a scale model of a side lever engine, copied from the engine of the "*Leven*," the first vessel to be engined by Robert Napier, founder of the now famous firm of engineers named after him. Each side of the frame of the model is built up from 12½" and 5½" Angle Girders, 3½" Strips and 3½" Angle Girders being used to connect the two sides together. The cylinder, which is built up from two Face Plates and sixteen 3½" Strips held in place by Flat Brackets and ½"×½" Angle Brackets, is attached by four ½" Bolts to a 3½"×2½" Flanged Plate. This Flanged Plate is secured to the frame of the model by 2½" Flat Girders. The piston gland on the upper end of the cylinder is represented by a Double Bent Strip through the centre hole of which the piston rod passes.

The condenser is built up from three 3½"×2½" Flanged Plates and two 2½"×2½" Flat Plates, and is situated close to the cylinder as shown in the photograph. Two cylinders are bolted to the condenser, each of which is composed of a Sleeve Piece and a ¾" Flanged Wheel. These represent the bilge or waste pumps, the pump rods being operated through a series of levers and cranks from one of the Eccentrics on the crank-shaft, as shown in the illustration.

The piston rod, a 4½" Rod, is connected by a Double Arm Crank to a channel section girder built up from two 4½" Angle Girders. Each end of these two Girders carries a Double Bracket the underside lugs of which are connected together by a 4½" Strip. The method of connecting the 4½" Angle Girders to the beam is shown clearly in the illustration.

The connecting rod is built up as illustrated, and is pivotally attached at its upper end to the crank, which consists of two Cranks locked securely together by a ½" Bolt. Each half of the crankshaft, a 2½" Rod, carries a Triple Throw Eccentric, one of which has already been described. The other is coupled by a 7½" Strip to a 2" Strip that operates the valve rod through a series of levers shown plainly in the illustration.

There remains to be fitted the air-pump. A 3½"×2½" Flanged Plate is secured to the base of the model by means of two 2½" Flat Girders, and to the upper face of this Plate are attached two Boiler Ends secured together by four Flat Brackets and attached to the Plate by four Bolts. The pump rod is attached to a horizontal Rod by a Coupling, this latter Rod being linked to the side levers by 2½" Strips.

The side lever engine held the field against all competitors for many years, and it was a very suitable engine for its type of work, the pumps and other auxiliaries being driven with little or no difficulty from the beam. Its main disadvantage lay in its great weight, and in the number of its moving parts, this latter point being of great importance when the efficiency of the engine is considered. Among the engineers who were trying to eliminate the clumsy and weighty double beam was Joseph Maudslay, who designed several different types of engines.

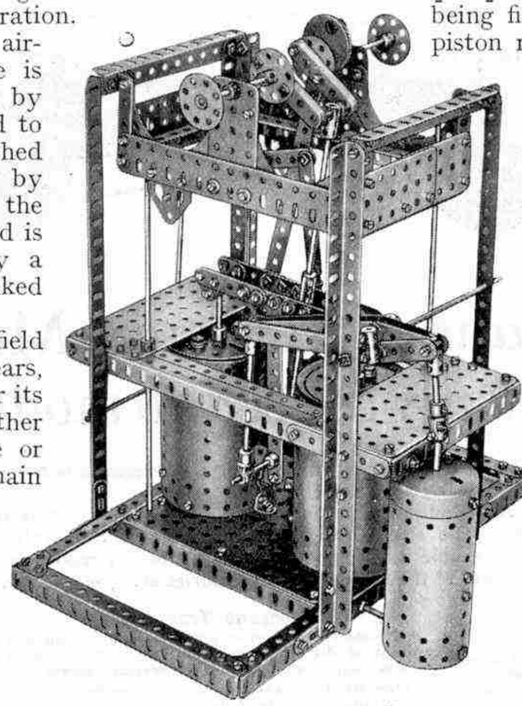

Fig. 2. A tandem paddle engine the original of which was designed by Joseph Maudslay.

One of Maudslay's early experiments resulted in the "steeple" engine which, although efficient in operation, was tall and weighty, no less than nine heavy pieces of metal being required to replace the simple connecting rod. Maudslay also invented the trunk engine which, like a petrol engine, dispenses with a piston-rod altogether, the connecting rod being attached direct to the piston. In this engine the piston was fitted at its centre with a large diameter tube that protruded from the cylinder at each end, and the connecting rod was pivoted in the centre of this. The great disadvantage of this engine lay in the greatly reduced piston area and the alternate heating and cooling of the trunk as it moved in and out of the cylinder. The necessarily large stuffing boxes also caused considerable friction and still further reduced efficiency. The trunk engine therefore never found favour with engineers for driving paddles, although it was revived later for driving screw propellers when piston speeds were increased.

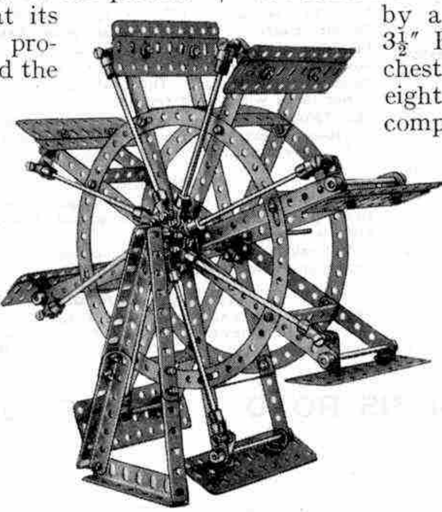

Fig. 3. A "feathering" paddle wheel suitable for fitting to any of the engines described in the article.

One of Maudslay's most successful engines is shown in model form in Fig. 2. The base of the model consists of two 12½" and two 7½" Angle Girders joined together by Corner Brackets at each corner to form a rigid structure. In the centre of this frame is secured a platform, built up from 7½" Angle Girders and 5½"×3½" Flat Plates, on which the cylinders rest. Each cylinder consists of two boilers, minus ends, opened out so that when bolted together they fit round the periphery of a 3" Pulley. The upper ends of these cylinders consist of 3" Pulleys held in place by 1"×½" Angle Brackets.

The cross-head slide bars, 3½" Strips, are bolted one to each cylinder as shown by ⅜" Bolts, Washers being used for spacing purposes between the cylinders and 3½" Strips. The cylinders are now attached to the base by means of ½"×½" Angle Brackets the piston rods also being fitted, represented by 4½" Rods. The piston rods are coupled together by a yoke built up as illustrated, and to this is bolted two 5½" Strips, at the lower ends of which the crosshead is attached. This crosshead consists of two 1½" Flat Girders secured together by two Double Brackets, Set Screws being used in place of ordinary Bolts for clearance purposes. The crosshead carries a short Rod that connects the piston yoke to the connecting rod, and it carries also a Small Fork Piece that couples the condenser pump to the main engine through the medium of the small beam as shown. The piston rod of the air pump is journalled, inside the cylinder, in the end hole of a 1"×1" Angle Bracket.

Each web of the crankshaft consists of six 2½" Strips bolted by ⅜" Bolts to a Bush Wheel, and the crank-pin is attached to the webs by means of Cranks. The valve derives its motion from an Eccentric on one side of the crankshaft, a 7½" Strip attached to this coupling it to a Double Arm Crank mounted on a horizontal Rod that is partly shown in the illustration. The opposite end of this Double Arm Crank carries a 5½" Strip, the upper end of which is locknutted to a 3½" Strip mounted on a 5" Rod supported in Flat Trunnions attached to the main bearings. The 3½" Strip is mounted two holes from one end, and the long portion is attached, by a 3½" Strip and an End Bearing, to a 3½" Rod forming the valve rod. The valve chest is built up from two Bush Wheels and eight 3½"×½" Double Angle Strips, the complete fitting being held in place by means of ½"×½" Angle Brackets.

About the year 1827 Maudslay introduced his first oscillating cylinder engine. This met with immediate universal approval, and in a very few years almost every paddle-propelled vessel was fitted with engines of this type. Even up to quite recently oscillating engines have been fitted into certain vessels where space was very restricted.

A model of a set of early paddle engines, copied from those of the "*Leinster*," a mail boat of 1860, is shown in Fig. 4. From this illustration it will be seen how neatly engines of this type could be fitted into a vessel, minimum space and perfect balance being the outstanding features of the installation. This model is shown inside a section of the hull of an early paddle boat, but if desired the hull may be dispensed with and a framework substituted. Each of the main bearings supports is built up from a 12½" Angle Girder and a 12½" Flat Girder, their ends being bolted to each side of the hull section or framework.

When these two main supports are in place they are connected across by the four main bearings shown in the photograph, each of which consists of two 1½" Angle Girders and three 3½" Strips. The 1½" Angle Girders protrude below the main supports and these ends are fitted with 2½" Small Radius Curved Strips and 1" Corner Brackets as shown.

Each of the two cranks consists of two separate webs, one of which is built up from six 1½" Strips and two Cranks, and the other from six Flat Trunnions and two Cranks. The crank-pin is represented by a 1½" Rod and the big-end by three Couplings held together by two 1" Threaded Rods. The crankshaft also carries two single throw Eccentrics and a third crank, this latter being composed of two Couplings and a 1" Rod. The two connecting rods on this crank are built up from 1½" Strips and End Bearings, the End Bearings being attached to 2" Rods. These Rods form the pistons of the two condenser pumps, both of which are mounted on ⅜" Bolts. The Bolts for each pump are supported in the end holes of two 1"×1" Angle Brackets that are attached to one of the two main cylinder supports by two 1" Triangular Plates.

The two oscillating cylinders are each built up from two Face Plates joined together by means of eight 3½"×½" Double Angle Strips. The spaces between the Double Angle Strips are filled in by 3½" Strips held in place by Flat Brackets. It should be noted that one of the Double Angle Strips and its attendant Strip is made detachable by clamping the securing nuts in place by ½"×½" Angle Brackets. Two valve chests are fitted to each cylinder, these being built up from Channel Bearings and 1"×½" Angle Brackets. They are fitted in place as shown in the photograph and the two valve rods are connected together by two Flat Brackets and one 2½" Strip, bent slightly as desired. The 2½" Strip is locknutted at its centre to a second 2½" Strip bolted at its upper end to one of the single throw Eccentrics that have already been referred to in this article.

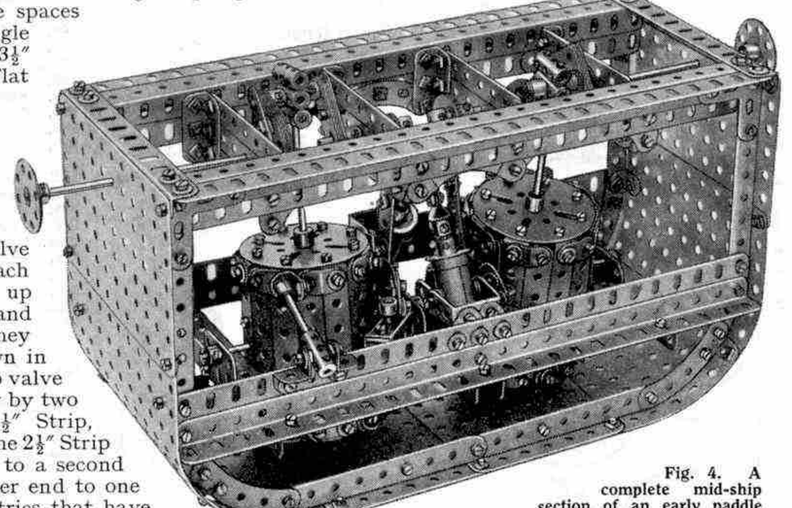

Fig. 4. A complete mid-ship section of an early paddle boat showing the oscillating cylinders.

The cylinder pivots, which in the actual engine consist of the steam inlet and exhaust pipes, are represented in the model by a Crank Shaft locked rigidly to the cylinders by Double Arm Cranks. These Crank Shafts allow the piston rods free movement in the cylinders. The ends of each cylinder pivot are mounted in the centre hole of a 1½" Flat Girder attached by a 5½" Angle Girder to a main cross member of the hull section.

To complete the model two subsidiary pumps are fitted. Each of these is built up from a Coupling mounted on the shanks of two Bolts that are supported in Corner Angle Brackets, one right-hand and one left. The pump rod, a 2" Rod, is fixed by a Collar to a Flat Bracket bolted to the cylinder top.

Paddle Wheels of the "feathering" type

The paddle wheel shown in Fig. 3, is provided for the benefit of those wishing to fit paddles to any of the models described in this article. It is of the "feathering" type, and will greatly enhance the appearance of any model to which it is fitted. The two hub centres are represented by Bush Wheels mounted on a suitable Rod and spaced apart for a distance of 2½" by means of Couplings and Collars. Each Bush Wheel carries eight spokes formed from 5½" Strips, which are braced by a 7½" Circular Strip, bolted in place as shown in the illustration. The two halves of the paddle wheel are coupled together by means of eight 2½"×½" Double Angle Strips.

Each paddle float consists of two 4½" Flat Girders joined together to form a double width flat girder, and the complete float is attached to the wheel by 1"×½" and ½"×½" Angle Brackets. The 1"×½" Angle Bracket is fitted with a Pivot Bolt on which a Small Fork Piece is free to swing. This Fork Piece is connected by a 4½" Rod and End Bearing to a Bush Wheel that, in the model, is supported on a framework of Angle Girders. In actual practice this part of the paddle wheel is carried on the outer edge of the paddle box, its work being to "feather" the floats. This means that the floats are made to enter and leave the water in a vertical position, thus increasing the efficiency of the paddle. It should be noted that one of the rods connecting the floats to the "feathering" mechanism is bolted rigidly to the Bush Wheel, but all the others are free to pivot.

No history of marine engineering would be complete without mentioning the "*Great Eastern*," which at the time of her launch in 1858 was nearly twice as long as the largest ship in the world, and considered to be absolutely impregnable to attacks from either wind or sea. She was double-hulled, and it was estimated that the space between her two hulls would hold 2,500 tons of water ballast if necessary. She was 680 ft. long, 82 ft. 6 in. wide and 58 ft. deep. Transverse bulkheads divided her into a series of 60-ft. compartments.

"Great Eastern" too far in advance of the times

This remarkable ship was equipped with paddles and a screw propeller, and sails were fitted on her six masts. Her designer, the famous engineer Isambard K. Brunel, hoped that she would attain a service speed of 15 knots, but she never came up to expectations. Commercially she was a failure, but this was due almost entirely to the fact that she was too far in advance of the times, and thus never really had a fair chance.

The paddles of the "*Great Eastern*" weighed 836 tons and were driven by two double-cylinder oscillating engines having a total indicated horse power of 3,411. The cylinders were 6 ft. 2 in. in diameter, with a stroke of 14 ft., and each weighed 28 tons. The engines could be worked independently if required. Apart from the number of cylinders these engines were almost identical with the oscillating engines already described. For screw propulsion the "*Great Eastern*" was equipped with a huge four-bladed cast iron screw 24 ft. in diameter, and of 44 ft. pitch. The shaft of the propeller was 150 ft. long. The screw was driven by horizontal direct acting engines with a total indicated horse power of 4,886. When driven by both screw and paddles the ship attained a speed of 14½ knots, by the screw alone her speed was about nine knots, and under her paddle wheels alone about seven knots.

The launching of the "*Great Eastern*" was fixed for 3rd November, 1857, but on that occasion the great ship moved only a few feet and then stuck fast, and it was not until 31st January, 1858, that she actually took the water. Her bad luck began with her first trial in September, 1859, for an explosion occurred that resulted in the death of six men and injuries to several others. Her first voyage was from Southampton to New York, and was accomplished in 11 days. The return trip was made in 9 days 11 hours. In 1861 she carried over 2,000 troops to Quebec and returned to Liverpool with about 500 passengers.

The only work on which the "*Great Eastern*" could be really successfully employed was that of cable laying, for which her great size was very valuable in enabling large quantities of cable to be carried on board. In 1868 she was employed on laying the Atlantic cables and she continued on this work at intervals until 1886. No other suitable work at sea could be found for her, and in that year she was bought by a firm of drapery and tea merchants and subjected to the indignity of being used as a kind of show place for advertising purposes. Four years later she was sold to be broken up, and thus ended her career.

Development of high steam pressures

It should be remembered that steam pressure also has played a tremendous part in the fight for efficiency in marine engines, and although it is not intended to discuss boilers and steam generating plant generally in these articles, a short comparison will doubtless help the reader to realise the tremendous change that has overtaken marine engines in this direction. The very early engines worked at a boiler pressure of between two and 7 lb. per sq. in., and anything over this was considered undesirable, one firm going so far as to ask Parliament to prohibit the use of steam generated at pressures of more than 10 lb. per sq. in.! These ideas have passed with the greatly improved metals now obtainable, however, and to-day it is quite commonplace for marine engines to have a working pressure of 250 lb. per sq. inch, and over. Recent experiments have shown that such a pressure is far from being the practicable limit, and although difficulties still present themselves in regard to material, it is certain that before long far higher pressures will be adopted.

British Marine Engine History in Meccano

III.—Screw *versus* Paddle Wheel

THE disadvantages of paddle wheels were realised from their earliest application to ships, their main drawbacks being their great weight and unwieldiness, the undesirable greater beam that they added to vessels, and their varying efficiency owing to the difference in the draft of a vessel when loaded with different cargoes. As regards warships, the drawbacks were even more serious. The wheels were exposed to gun-fire, and some of the propelling machinery had to be placed above the waterline. In addition, the position and size of the side wheels limited the number of guns that could be used for broadside firing. It is not surprising, therefore, that marine engineers and others interested in the development of the steamship were continually on the look-out for a more efficient means of propulsion.

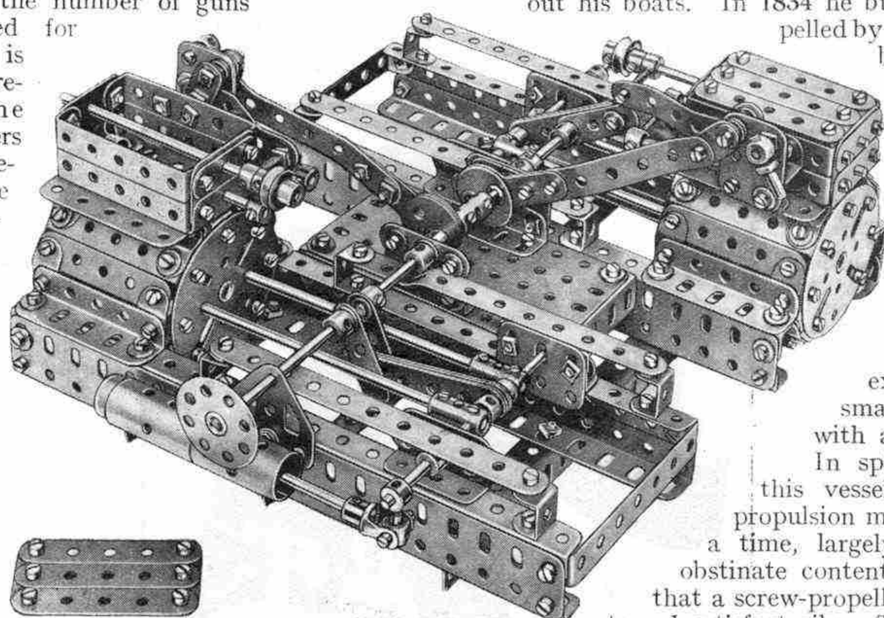

Fig. 1. A return connecting rod engine, one of the earliest high-speed screw engines.

The paddle steamers of those days were small, and in a heavy beam wind were liable to heel over so far as to bury the paddle on one side far below its efficiency point, while the paddle on the other side was half out of the water. An amusing story is told of the days, towards the end of the 19th century, when the St. George Company and the Isle of Man Steam Packet Company were competing desperately for the passenger traffic between Liverpool and the Isle of Man. The "*St. George*," belonging to the former company, and the "*Mona's Isle*," owned by the latter, were to sail at the same time on a certain morning. On the previous day a strong wind was blowing, and the captain of the "*Mona's Isle*," confident that this wind would prevail next day, had the cargo and coal shifted to the windward side of his vessel during the night. On the following morning the "*St. George*" steamed out of the Mersey in perfect trim, whereas the "*Mona's Isle*" heeled over to such an extent as to cause general astonishment and amusement. As soon as the protection of the land was lost, however, the "*St. George*" heeled over before the strong wind, while the "*Mona's Isle*" went ahead on an almost even keel with both paddles working at their maximum efficiency, so that she soon outstripped her rival.

Screw propulsion as an alternative to the paddle wheel had been considered for many years, but the early experimenters, though full of sound ideas, did little to put forward practical schemes. It was not until 1836 that really serious efforts were made to apply the screw to steam vessels. In that year experiments that had far-reaching results were carried out by Francis Pettit Smith. Smith was born in 1808 at Hythe, in Kent, where his father was Postmaster, and as a boy he was passionately fond of constructing models of boats. When he grew up he became a farmer on Romney Marsh, and afterwards moved to Hendon, where the reservoir of the old Welsh Harp provided him with an ideal water on which to try out his boats. In 1834 he built a tiny vessel propelled by a wooden screw driven by a spring, and the performance of this convinced him that the screw was far more efficient than the paddle wheel. He received financial assistance, and during the next few years he carried out a series of successful experiments with a small steam vessel fitted with a wooden screw.

In spite of the success of this vessel, the idea of screw propulsion made little headway for a time, largely on account of the obstinate contention of Naval officials that a screw-propelled vessel could not be steered satisfactorily. The superior efficiency of the screw could not long be denied, however, and after about 1860 screw propulsion became practically universal, both for merchant and Naval vessels.

Another pioneer of screw propulsion, Captain J. Ericsson, a Swede, must be mentioned. He was in England at the time when Smith took out his patent, and was then perfecting a propeller of his own. He built a boat 40 ft. in length fitted with two propellers, which proved very successful. He invited the Admiralty to see it, but they turned it down, as they had turned down Smith's invention, "because it would be absolutely impossible to make the vessel steer." After this rebuff Ericsson went to the United States, where he succeeded in interesting the Government in his propeller, but without gaining much reward for his labour.

The early screw engines were practically the same as the paddle engines, with the exception that, owing to the higher shaft speeds that were necessary, gearing had to be employed. The "*Great Britain*," for instance, the first screw steamer to cross the Atlantic, was fitted with oscillating engines arranged to drive a large spur wheel that engaged with a spur pinion on the propeller shaft. For the first few years after the introduction of the screw no new type of engine was developed, those employed being adapted beam, side lever, and oscillating engines.

When the problem became better understood, however, engineers began to abandon geared engines altogether in favour of properly designed quick-running, direct-acting engines. These engines were lighter, and considerably less bulky, and generally were more efficient on account of their higher piston speeds.

One of the great difficulties that the engineers were faced with at this time was the length of the connecting rod necessary for economical working; and as the vertical type of multi-cylinder engine had not yet been designed, this proved a difficult problem. It was overcome in various ways, the earliest success being the return connecting rod engine, a type that was widely used up to the close of last century in both commercial and Naval steamships. A model of an engine of this type is shown in Fig. 1, which is a scale reproduction of the engine fitted into the British frigate "*Amphion*" in 1844. This was the first engine of the type to be built, and for this reason it is particularly interesting.

The complete power unit is built up as two single cylinder engines, each cylinder being composed of two Face Plates secured together by seven 2½"×½" Double Angle Strips. The spaces between these Double Angle Strips are filled in by means of 2½" Strips held in place by Flat Brackets. Two 2½" Angle Girders, fitted as shown, are used to secure the cylinder to the two side members, each of which is built up from two 9½" Angle Girders and one 9½" Flat Girder. The two members are connected together at their unsupported ends by a 3½"×½" Double Angle Strip. The two piston rods, 6½" Rods, are coupled to the crosshead by Couplings, the crosshead being built up from a 4½" Rod and two slides held in place by Double Arm Cranks. Each slide is represented by a 1½" Flat Girder and two 1½" Angle Girders.

One end of the crosshead rod overlaps the outer side-member supporting the cylinder, and carries a Swivel Bearing to which is attached the condenser pump rod. The connecting rod is supported on the crosshead rod between two Collars and is attached to the crank by means of a ⅜" Bolt. The valve chest, the cover of which is shown in the bottom left-hand corner of Fig. 1, is fitted with two valves, one hand operated for starting, and the other by an Eccentric on the crankshaft. It should be noted that the hand-operated valve and its actuating lever are dummies, but the valve operated from the crankshaft is coupled up as indicated.

When the two cylinder units are complete they are secured together by three 9½" Angle Girders, and a 4½" Flat Plate is fitted as shown to form an operating platform from which, in actual practice, the engine is controlled.

We now come to a period when a vast amount of experimental work was carried out by both engineering firms and private individuals, the result of which was the production of a great variety of marine engines, each claiming some special advantage. These engines, however, with one exception, were all direct-acting, and fitted with piston rods and connecting rods. The exception was an engine built by Captain Ericsson, mentioned earlier in this article, and it was designed with the object of reducing the mass of moving parts. It was operated by two rocking segments working in specially-designed cylinders, the vibrations thus set up being transmitted through a series of long and short cranks to the propeller shaft. The air pump and other auxiliaries were driven from the first stage of vibrating cranks. Although this type of engine was effective in operation, it became obsolete as workmanship improved and it became possible to attain the necessary balance to enable great masses of metal in the moving parts to work in absolute safety even at very high speeds.

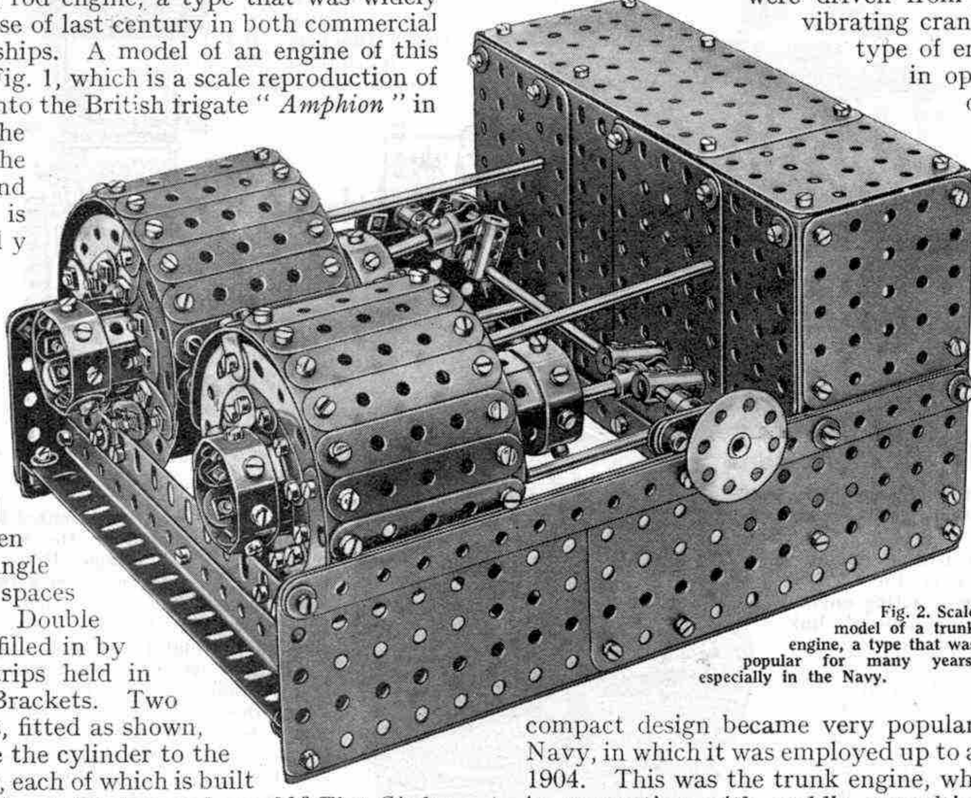

Fig. 2. Scale model of a trunk engine, a type that was popular for many years, especially in the Navy.

Another type of engine came to the fore at this period, and on account of its low centre of gravity and compact design became very popular, especially in the Navy, in which it was employed up to as recently as about 1904. This was the trunk engine, which was mentioned in connection with paddle propulsion in the previous article.

The trunk engine is shown in model form in Fig. 2. Each fore and aft side member of the main frame is built up from a 7½" Angle Girder and a Flat Girder of similar length, the two complete sides being connected together by two end girders built up from 9½" Angle Girders and Strips and 5½"×2½" Flat Plates. The condenser is composed at each long side of 4½"×2½" Flat Plates bolted to 7½" Angle Girders and the top and ends are represented by 5½"×2½" and 2½"×2½" Flat Plates. Angle Girders of suitable lengths add strength to the structure.

The ends of the cylinders are built up from 2½" small radius Curved Strips and Flat Brackets, these latter parts being arranged on the inside of the circle formed by the Curved Strips, as shown in the photograph. The complete cylinder ends are secured together in pairs by means of 2½"×½" Double Angle Strips, and one of these holds the cylinder walls in place. The walls are made detachable and are represented by two pairs of 3½" Strips joined together and curved as shown, and fitted with twelve 2½" Strips. The complete walls must not be fitted until the trunk is in position. The trunk is composed of two 5½" Strips, bent until they form two circles, and round the inside of these are bolted ten 4½" Strips. These are secured in place alternately, so that when the edges of the Strips overlap they do so without allowing the bent 5½" Strips to lose their true shape. The trunks are placed inside the cylinders before one of their respective end 5½" Strips is fitted in place.

The little-end of each cylinder, a Small Fork Piece, is mounted on a 1½" Rod in the centre of the trunk, and the connecting rod is held at its inner end by this. At its outer end it is secured by a second Small Fork Piece to a 1" Rod forming the connecting pin between the two webs of the Crank. The crankshaft is built up as illustrated and its two main end bearings are each formed from a 1½" Flat Girder and a Double Arm Crank.

The pump rods, four in number, are represented by 6½" Rods, and are attached to the trunks by means of ½"×½" Angle Brackets, Collars being used to prevent the Rods moving longitudinally. It will be noticed that no valve-gear is fitted, this being missed out because of its complicated nature, and also because of the small scale to which the model is built.

Although the screw propeller is now universal for all ordinary steamships, paddle wheels are still employed in special types of vessels intended for use on rivers and other shallow waters. The engines usually fitted to these vessels are direct-acting, inclined-cylinder, compound units, low-built and remarkably efficient. In cases where it is necessary to manœuvre the vessel by varying the speed of the paddles in relation to one another, two separate engines are fitted.

A modern type of paddle engine is shown in model form in Fig. 3, this being a compound, direct acting engine, fitted with the usual Stephenson's link motion. The main longitudinal framing is composed of two channel section girders, each of which is built up from one 18½", one 7½", one 5½", one 4½" and one 3½" Angle Girders, all held together by two 12½" Flat Girders to form a compound girder 15½" in length. The 4½" Angle Girder, placed at one end of the channel section girder, is secured in place at an angle in order to give the cylinder block the required tilt.

When the two main girders are completed they are secured together by means of two "I" section girders, each of which is built up from 7½" Angle Girders and 7½" Flat Girders, Simple Bell Cranks being used to give strength to the complete frame. The fore end of this frame is secured to a specially shaped structure representing a section of the hull of the vessel. This is built up from a number of 5½"×3½" Flat Plates, bent to the required shape and held in this form by suitable Curved Strips and two 9½" Angle Girders, these two latter parts being bolted across the bottom of the "hull." Flat Girders and Angle Girders are now used as shown in the photograph in order to give a substantial appearance to the Curved Strips and 9½" Angle Girders.

The cylinder block is built up from 5½"×3½" and 4½"×2½" Flat Plates, 7½" and 3½" Angle Girders holding them rigidly together. One of the two sides of this unit is built up from two 4½"×2½" Flat Plates, the securing nuts being placed on the outside of the finished cylinder block, giving the impression of a slide-valve chest cover. The other side of the cylinder block does not carry the nuts outside, as the valve at this point is one of the ordinary piston type. The cylinder heads of the low-pressure and high-pressure cylinders are represented by 2" and 3" Pulleys respectively.

The crankshaft bearing supports, three in number, are each built up from a Flanged Sector Plate fitted at each side with a 5½" Angle Girder by means of which the Sector Plate is secured to the main frame. The upper ends of the Sector Plates are finished off as shown by 2½" Angle Girders, and are held in place by means of Flat Brackets bent to the required shape. The crankshaft bearings are represented by pairs of Double Arm Cranks.

The slide bars, which also form the upper bracing members of the engine, are built up from 9½" Angle Girders. The inner slide bar, which is double, takes the shape of an "I" section girder, and the two outer ones are constructed in the form of channel section girders. ½"×½" Angle Brackets are used to attach these slide bars to the cylinder block and main bearings. Each of the crossheads is built up from 1½" Angle Girders and a 2" Threaded Rod, an 8" Rod being used as a connecting rod and a 4½" Rod as a piston rod. The construction of the cranks is shown in the photograph.

The top of the engine is fitted with a control platform and engineers' footway, the platform being built up from two 5½"×2½" Flat Plates supported on four legs. Two of these are formed from 1"×½" and ½"×½" Angle Brackets, but the remaining two have in addition a 2" Strip each, this arrangement bringing the platform almost level. The engineers' gangway is composed of two 9½" Flat Girders supported at the opposite end to the platform by a 1"×½" Angle Bracket. The handrails are built up from Healds and lengths of Spring Cord down the centre of which is passed 26 S.W.G. copper wire in order to hold the complete handrail comparatively rigid.

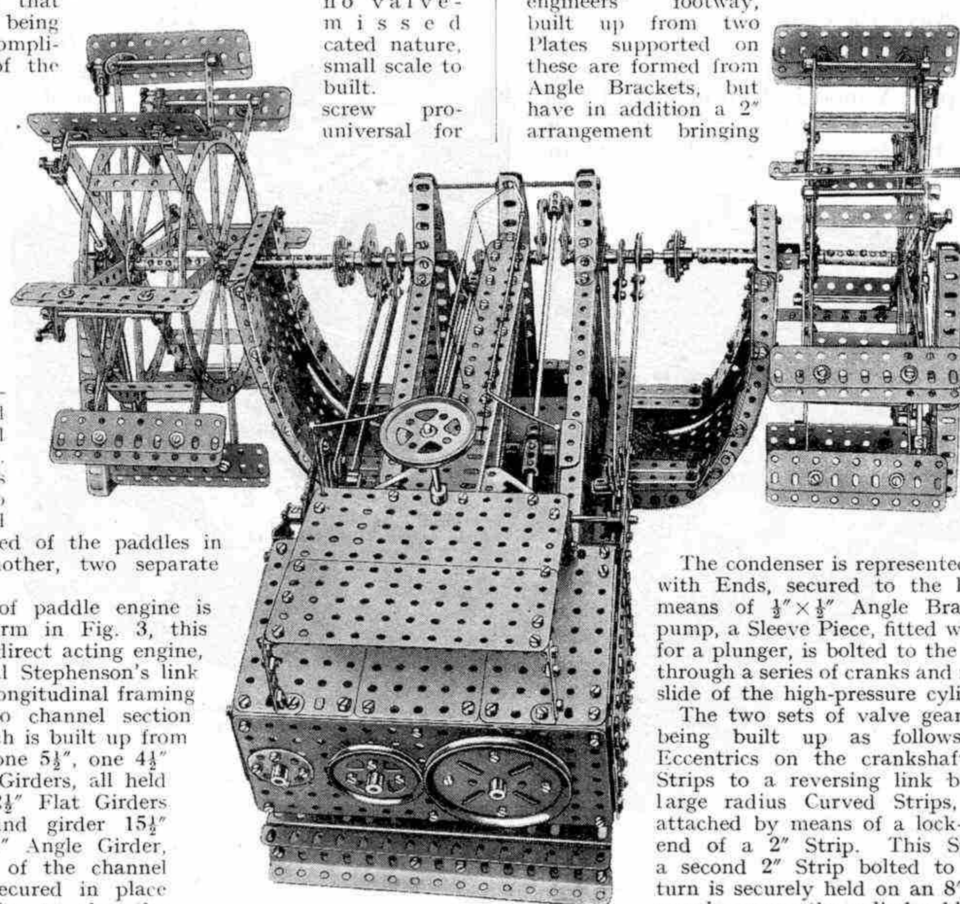

Fig. 3. A model of a modern paddle engine, illustrating the compact arrangement of a marine power unit of this type.

The condenser is represented by a Boiler, complete with Ends, secured to the lower main girders by means of ½"×½" Angle Brackets. The condenser pump, a Sleeve Piece, fitted with a Chimney Adapter for a plunger, is bolted to the Boiler, and is actuated through a series of cranks and rods from the crosshead slide of the high-pressure cylinder.

The two sets of valve gears are now fitted, each being built up as follows. Two single throw Eccentrics on the crankshaft are coupled by 7½" Strips to a reversing link built up from two 2½" large radius Curved Strips, and this is pivotally attached by means of a lock-nutted ⅜" Bolt to one end of a 2" Strip. This Strip is lock-nutted to a second 2" Strip bolted to a Crank, and this in turn is securely held on an 8" Rod supported transversely across the cylinder block by two 1½" Strips held in place by means of Trunnions. The centre of this Rod is fitted with a Double Arm Crank carrying a Small Fork Piece that is rigidly secured to the Crank by a Nut and Bolt. The threaded bore of the Small Fork Piece carries a 2" Threaded Rod coupled by means of a Threaded Coupling to a 2½" Rod. This Rod carries the 2" Pulley shown in the illustration.

The construction of the paddles was fully described last month in connection with the older types of paddle engines and therefore need not be described again in this article. The construction of the couplings forming a connection between the crankshaft and paddles is shown in the illustration, and the 2" Sprocket Wheel situated close to one of these is added in case it is desired to drive the model from a Meccano Electric Motor.

If a Motor is to be included in the model, it may be placed on short Angle Girders over the condenser and fitted with sufficient gearing to allow the paddles to rotate at about 50 r.p.m. This is not only the speed generally adopted in actual practice, but also it allows the working parts of the model to be clearly understood when it is in motion, the feathering paddle wheels being particularly interesting from this point of view.

The most important of the well-known early marine engines have now been described, the last example, a trunk engine, bringing us to the close of the nineteenth century, when the introduction of the vertical steam hammer type of engine revolutionized marine practice and brought about the commencement of the craze for higher speeds. A selection of models of these later types of engines will be dealt with next month, and the introduction and general operation of compound and tandem engines will be described.

British Marine Engine History in Meccano

IV.—The Reciprocating Engine Develops

IN last month's article we described the struggle between paddle wheels and the screw propeller, and the final adoption of the screw, towards the close of the 19th century, as the most effective method of marine propulsion. We showed also how, owing to the screw being a comparatively new thing, the means of operating it were for many years little better than experiments, the power units being at best effective only within narrow limits, and in many cases complete failures.

These early attempts, however, paved the way for scientifically-designed and better built engines that in time became more standard in general construction and more suitable for fitting into ships of almost any size. The main type of reciprocating engine that evolved is generally known as the steam-hammer engine on account of its close resemblance to the large forging hammers employed in iron and steel works. This type of engine no doubt would have come to the fore earlier but for the low freeboard and small draught of the early steamers; in warships, especially, the cylinder heads would have protruded far above the waterline and thus have been vulnerable to gunfire. This difficulty was overcome as the size of ships increased, and although in the early days of their introduction the engines had to be protected at their upper ends by armour, they quickly found favour, and have remained without important change up to the present day.

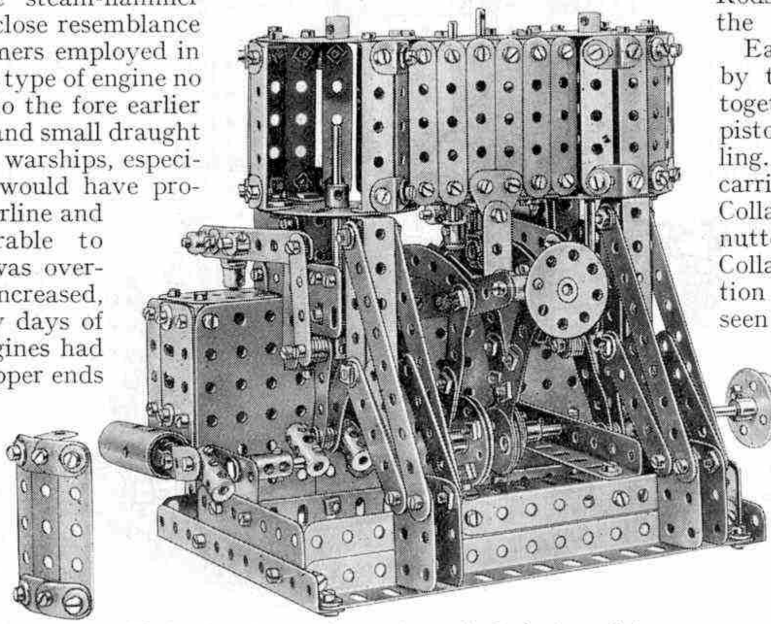

Fig. 1. An early steam-hammer type engine having two cylinders.

The majority of engines of this type were two-cylinder, simple-expansion, double-acting units, the cranks of which were set at an angle of 90 degrees to each other in order to overcome "dead centre." A model of one of these engines is shown in Fig. 1, the apparently odd section in the foreground being part of one of the cylinder walls, detached to show its construction and method of fitting.

The bed-plate of the model is built up from three 7½″ and two 5½″ Angle Girders, suitable Flat Girders being used as shown in order to give a massive appearance. To strengthen the complete frame 1″ Corner Brackets are used. The condenser is next built, its near side being constructed from two 5½″×3½″ Flat Plates, and the two ends from 2½″ Flat Girders and Angle Girders. The top and the rear are composed of 3″×1½″ and 5½″×2½″ Flat Plates, which are held in place by 7½″ Angle Girders.

The crankshaft is the next portion to receive attention. Each crank consists of two Couplings held together by a 1″ Rod, on which is carried the connecting rod represented by two 2″ Strips. The right-hand side crank is carried on a 3″ and a 2″ Rod, and the left-hand side crank on a 2″ and a 1″ Rod, this last part being lengthened by means of a Coupling and Threaded Pin. The Threaded Pin is fitted with a second Coupling that carries the connecting rod of one of the auxiliary pumps. The two complete cranks are coupled together at right angles by means of a flexible connection built up from two Bush Wheels and four ⅜″ Bolts. The ⅜″ Bolts are lock-nutted as shown.

The construction of the cylinder block is clear from the illustration, and needs no comment except that the valve rods slide in the bosses of Double Arm Cranks fitted inside the block. The frames supporting the cylinders are built up round the four slide bars, each of which is represented by four 2½″×½″ Double Angle Strips. The vertical frames are attached to these by means of 1″ Threaded Rods passing completely through the slide bars.

Each cross-head is represented by two 1½″ Flat Girders held together and attached to the piston rod by means of a Coupling. Each side of the cross-head carries a ¾″ Bolt fitted with two Collars, the Bolts being lock-nutted in order to allow the Collars to rotate. The construction of the valve gear will be seen from the photograph.

Two 2″ Strips are pivotally attached to the lower edge of each cross-head, and are coupled by means of two 3½″ and two 1½″ Strips to a 1½″ Rod carrying the circulating pump connecting rod. The two 3½″ Strips are pivoted as shown on a 1½″ Rod. The circulating pump, and its facsimile the air pump, are built up from two Bush Wheels and six 1½″×½″ Double Angle Strips, the complete pumps being secured to the rear of the condenser by two Bolts each.

Soon after marine engines began to conform to a definite general design, compounding was introduced, this practice having been first applied to locomotives by Messrs. Samuel and Nicholson, of the Eastern Counties Railway, in 1852. The system as applied to ships met with immediate success, and two-cylinder compound engines were soon followed by triple and quadruple expansion types. In these engines the steam first entered the high-pressure cylinder, and after doing work there passed into a receiver where it remained until the valve opened to admit it into the next cylinder. Here it cooled, and if the engine was a two-cylinder compound the steam passed into the condenser, where it became water once more and was ready for using over again in the boilers. Triple and quadruple expansion engines used steam in an exactly similar manner, except that expansion was spread out over three or four cylinders, a receiver being incorporated between each separate stage of expansion.

All big vessels built after the introduction of compounding were fitted with triple or quadruple expansion engines, the cylinders of which were arranged in one line, and a separate crank used for each. In older vessels, however, this system was impracticable on account of restricted engine room space, more than two cylinders in line being very rarely used in simple expansion engines. It was a great advantage to fit these vessels with compound engines, however, and a system of tandem cylinders was therefore introduced in order to overcome the difficulty. In these engines the cylinders were arranged one above the other in pairs, each pair having one common connecting rod and crank. In this manner most of the advantages of three and four stages of expansion were obtained with only a slight increase in height, and as this could readily be accommodated by the removal of the upper deck, the efficiency of a vessel so fitted was considerably increased without the cargo-carrying space being affected. This type of engine lasted only as long as these older vessels were afloat, however, and therefore in recent years it has entirely died out, new vessels now being built to accommodate longer but lower engines.

An excellent scale model of a four-cylinder, triple-expansion, tandem engine is shown in Fig. 2, the cylinders of this being so arranged as to give one high-pressure, on intermediate—and two low-pressure cylinders.

Commence building the model by constructing the base, each side of which is formed from a 9½″ Angle Girder and a 9½″ Flat Girder. These two members are coupled together by four 5½″ Angle Girders and Flat Girders of similar length, the complete base being made rigid by four large Corner Brackets. One 3½″ Angle Girder and two 1½″ Angle Girders are now attached by means of 1½″ Strips to the near side of the base as shown, and the outer edges of these carry the lower ends of the 5½″ Angle Girders representing the outer vertical frames. The inner vertical frames are built up from 2½″×½″ Double Angle Strips, 2½″ Strips and Channel Bearings, the Double Angle Strips forming one side of the slide bars. The other side is formed from one 2½″×½″ Double Angle Strip and two 2½″ Strips, and the complete unit is secured at the top by a Double Bracket and at the bottom by two Flat Brackets and a Double Bracket. The cross-heads are each formed from two 1½″ Flat Girders held together and attached to the piston rod, a 6½″ Rod, by a Coupling. The connecting rod, represented by a 3″ Rod, is secured pivotally to the cross-head by a Small Fork Piece and to the crankshaft by a Coupling. The construction of the crankshaft and valve gears is shown in Fig. 2.

Each of the two low-pressure cylinders is composed of two Face Plates connected together by five 3½″×½″ Double Angle Strips, the spaces between the Double Angle Strips being filled in by 3½″ Strips held in place by Flat Brackets. An extension is fitted to one side of the cylinder to represent the slide valve chest, and this is built up from two sets of 2½″ large radius Curved Strips and a 1½″ Flat Girder connected together by 3½″ Strips. These 3½″ Strips are carried on suitably-shaped 2½″ Strips. The valve chest cover is composed of three 3½″ Strips held together by two 1½″ Strips and attached to the valve chest by means of four Bolts, the holding Nuts of which are placed outside for accessibility.

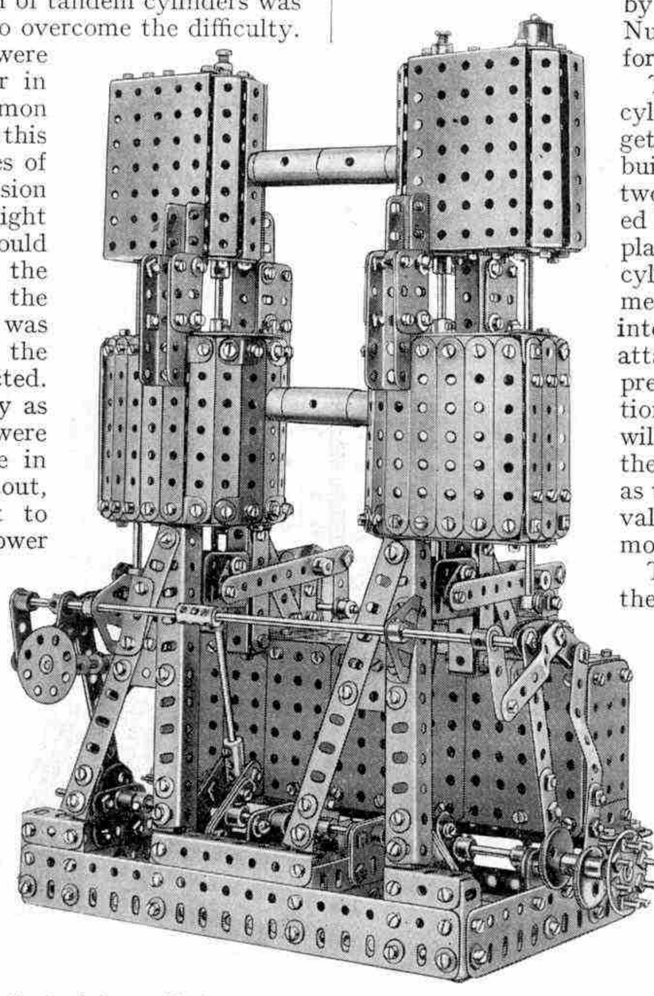

Fig. 2. A fine model of a tandem engine, a type of power unit adapted for use in old vessels as described in this article.

The two complete low-pressure cylinders are now connected together by a dummy steam pipe built up from a Sleeve Piece and two Chimney Adaptors, a 2″ Threaded Rod being used to hold them in place. The upper part of each cylinder carries two supports by means of which the high- and intermediate-pressure cylinders are attached to their respective low-pressure cylinders. The construction of the high-pressure cylinder, it will be noted, differs slightly from the intermediate-pressure cylinder, as the former is fitted with a piston valve instead of a slide valve, common to the other cylinders.

The arrangement for operating the air and circulating pumps is similar to that described for Fig. 1, except that the pumps are built up from 2½″×½″ Double Angle Strips instead of 1½″×½″ Double Angle Strips.

Although at this period almost all marine engines were of the vertical, reciprocating type, for some purposes horizontal direct-acting engines were still employed, good examples of these being found in the light cruisers and destroyers built during the latter part of last century. These engines were intended for very fast and light vessels having little draught and low freeboard, and in which weight was the main consideration. In general appearance they resembled the return-connecting rod type of engine described last month, but a direct-acting connecting rod was used in place of the return arrangement of the earlier power plant. The great disadvantages of these engines were the short connecting rods and uneven cylinder wear, and for these and other reasons they became obsolete as soon as fast naval vessels became large enough to accommodate vertical direct-acting engines, without the use of too much armour.

We now come to the period when fast direct-acting vertical engines definitely became established as the best and most efficient type for marine work, and from about 1900 onward all but the smallest vessels were fitted with either triple- or quadruple-expansion vertical engines. Triple-expansion engines have usually found more favour than those having four stages of expansion, on account of their smaller bulk and fewer main shaft bearings, this latter point being of major importance, for the longer the bed-plate of the engine the greater are the possibilities of its being distorted, thereby decreasing the efficiency of the engine through friction.

Now that one type of engine had definitely become generally accepted it was natural that engineers should give more thought to its efficiency and the possibilities of higher speeds, and it was not long before a race for faster and more powerful vessels began, especially between the countries of the Western seaboard of Europe. Foremost among these were England, Germany and France, Holland and Italy coming later as their knowledge of marine engineering increased. As a result of this competition British engineers, and especially those from Clydebank, designed and constructed some remarkably fast, light and efficient engines, most of which were three-cylinder, triple-expansion power units. As competition increased the call for higher speeds became more and more insistent until by about the year 1906 the majority of vessels, large and small, were driven by amazingly efficient triple- and quadruple-expansion engines, those fitted into the bigger liners being capable of driving the vessels at speeds of over 18 knots. This was the climax of the high-speed reciprocating engine, however, for about this time the possibilities of the turbine method of propulsion were beginning to be realised. From then onward reciprocating engines began to decrease in number, and were applied only to slower ships, such as cargo vessels and oil tankers. The introduction and rapid climb of the turbine will be described next month.

For ships in which high speed is of less importance than absolute reliability combined with simplicity, reciprocating engines still reign supreme, and they are so perfectly adapted to their task that it is unlikely that they will be replaced for many years to come by turbines or any other form of propulsion. A modern type of normal triple-expansion engine is shown in model form in Fig. 3. This is a particularly fine model, and gives a graphic idea of the compact and symmetrical design of engines of this type.

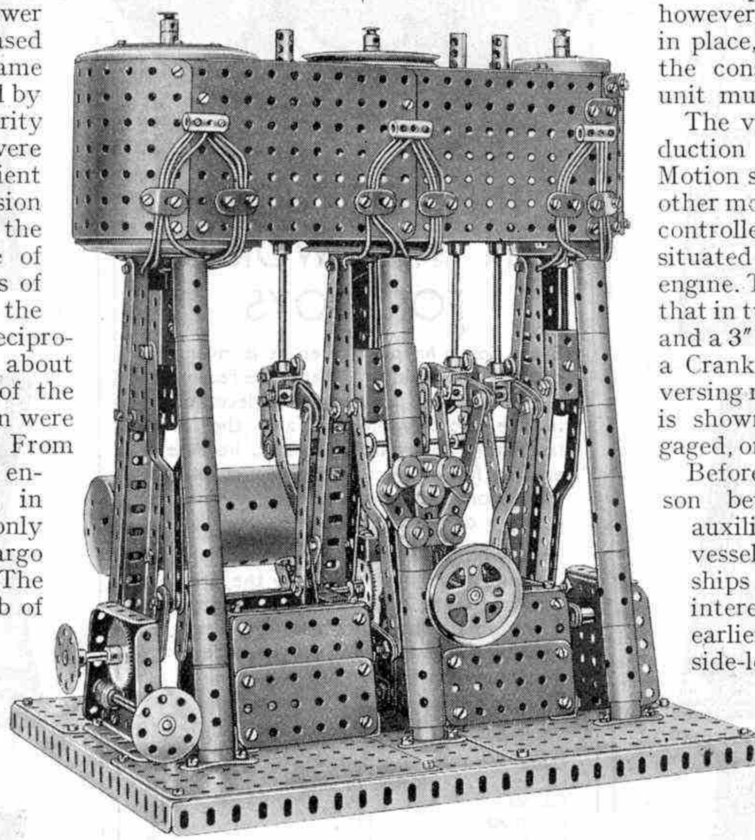

Fig. 3. The compact and efficient appearance of a modern marine engine is well illustrated by this fine Meccano model.

The base of this model differs slightly from that of the two previous models described in the article, as it represents the floor of the engine room and not the actual bed-plate of the engine. It is constructed from two $12\frac{1}{2}''$ and two $9\frac{1}{2}''$ Angle Girders, the frame so formed being covered in by $5\frac{1}{2}''\times3\frac{1}{2}''$ Flat Plates. A space $2\frac{1}{2}''$ wide is left between the two rows of Flat Plates, and the inner edges of the Plates are supported on two $12\frac{1}{2}''$ Angle Girders. Each of the main shaft bearings is constructed from a $2\frac{1}{2}''\times2\frac{1}{2}''$ Flat Plate and three $2\frac{1}{2}''$ Angle Girders, the complete bearing being secured in place by a $3\frac{1}{2}''$ Angle Girder. The four inner bearings are coupled together in pairs by $3''\times1\frac{1}{2}''$ Flat Plates. The construction of the crankshaft is shown in the illustration.

The rear cylinder block supports are each built up from two $9\frac{1}{2}''$ Angle Girders held in place at their lower ends by means of $1''\times1''$ Angle Brackets. The slide bar is secured to the upper end of the support, and is represented by two $3\frac{1}{2}''$ Flat Girders, arranged by means of Flat Brackets at their lower ends so that they lie in a perpendicular position when the cylinder support is set at its correct angle. The supports on the near side each consist of a $6\frac{1}{2}''$ and a $3''$ Rod secured together by a Coupling and held in place at the lower end by a Double Arm Crank. At its upper end this compound rod is attached by a Coupling and $1''\times1''$ Angle Bracket to the under side of the cylinder block. The solid appearance is given to the rod by the use of Sleeve Pieces and Chimney Adaptors.

The cylinder block is shown clearly in the illustration and therefore needs no description. It should be noted, however, that the top is not bolted in place, this arrangement making the construction of the cylinder unit much simpler.

The valve gear is a scale reproduction of Stephenson's Link Motion similar to that fitted to the other models in this article, and it is controlled from the hand wheel situated on the near side of the engine. This wheel operates a Worm that in turn rotates a 57-teeth Gear, and a 3" Strip connects this Gear to a Crank mounted on the link reversing rod. The hand turning gear is shown with the Worm disengaged, on the near end of the engine.

Before going further a comparison between the engine room auxiliaries found in modern vessels and those found in earlier ships will no doubt prove of interest. A glance at one of the earlier engines, for example, the side-lever engine described in the April issue, will show how the main engine was made to operate practically all the pumps and other machinery in the engine room. The model named is a very good example, for the beams of the original engine were literally covered with levers operating a variety of pumps, valves, etc. As the construction of marine engines has progressed, however, more and more auxiliaries have been detached and driven by separate motors until, as will be seen from Fig. 3, not even the air and circulating pumps are operated from the engine. Thus the work of the main power unit is concentrated entirely on driving the propeller, while the auxiliaries are in many cases operated at reduced pressure through a reducing valve from the main steam supply. Even the condenser, shown in the model fitted to the frames of the engine, is often separate and placed between the engine room and boiler room.

Within the past three years reciprocating engines have undergone a considerable amount of alteration and improvement, especially in connection with the valves and valve gears; and some of these improvements, together with modern turbine installations, will be described in next month's issue.

British Marine Engine History in Meccano

V.—The Steam Turbine

AS was shown in last month's article in this series, the triple-expansion engine has been brought to a remarkable pitch of perfection; but there is little doubt that it is capable of still further improvement in various directions. So long as this type of engine is considered suitable for marine work, engineers will continue their efforts to increase its efficiency. In recent years special attention has been given to valve gears, and extensive experimental work has shown that there are great possibilities of improvement in such mechanisms. Stephenson's valve gear, which has been universally adopted, is now being slowly but surely forced from its dominating position by more efficient and compact drop-valve gears. Two of the most successful gears of this type are the Beardmore "Caprotti" gear and the "Emew" gear, in each of which the valves are similar to those employed in motor cars. The operating camshaft, driven by gears from the crankshaft, is situated either over or alongside the cylinder block, and carries three cams for each valve. Two inlet and two exhaust valves are usually employed for each cylinder, reversing being accomplished by sliding the entire camshaft and thus bringing into operation a separate set of cams.

We must now turn to the great rival of the reciprocating engine for marine propulsion—the steam turbine. In a very rudimentary form turbines were constructed centuries ago, but it was not until the late Sir Charles Parsons introduced the reaction turbine in 1894 that engineers took any serious notice of the possibilities of this type of engine. After an exhaustive series of experiments Parsons amazed everyone at the Diamond Jubilee Naval Review in 1897 with his 44½-ton vessel "*Turbinia*," which darted about among the lines of great warships at a speed of over 34 knots, and even outpaced with ease the fastest destroyer of that period.

The final propulsion machinery of this little vessel consisted of three separate pressure-compounded turbines, each driving a separate propeller. The high-pressure turbine was on the starboard shaft, the intermediate-pressure one on the port shaft, and the low-pressure one on the centre shaft. A separate turbine was fitted to the centre shaft for use in going astern. This was necessary on account of the inability of a turbine to reverse, which is one of the greatest disadvantages of this type of marine engine. Up to the present the disadvantage has been overcome successfully only by the provision of an extra turbine. The engines of the "*Turbinia*" are now preserved in the Science Museum at South Kensington, together with about 45 ft. of the after section of the vessel.

The demonstration given by the "*Turbinia*" at the Naval Review so impressed the authorities that they ordered two destroyers, the "*Viper*" and the "*Cobra*," to be fitted with the new form of marine engine. Unfortunately both these vessels were wrecked before exhaustive trials could be carried out, but the "*Viper*" had shown that she was capable of a remarkable speed, nearly 37 knots being registered on one occasion.

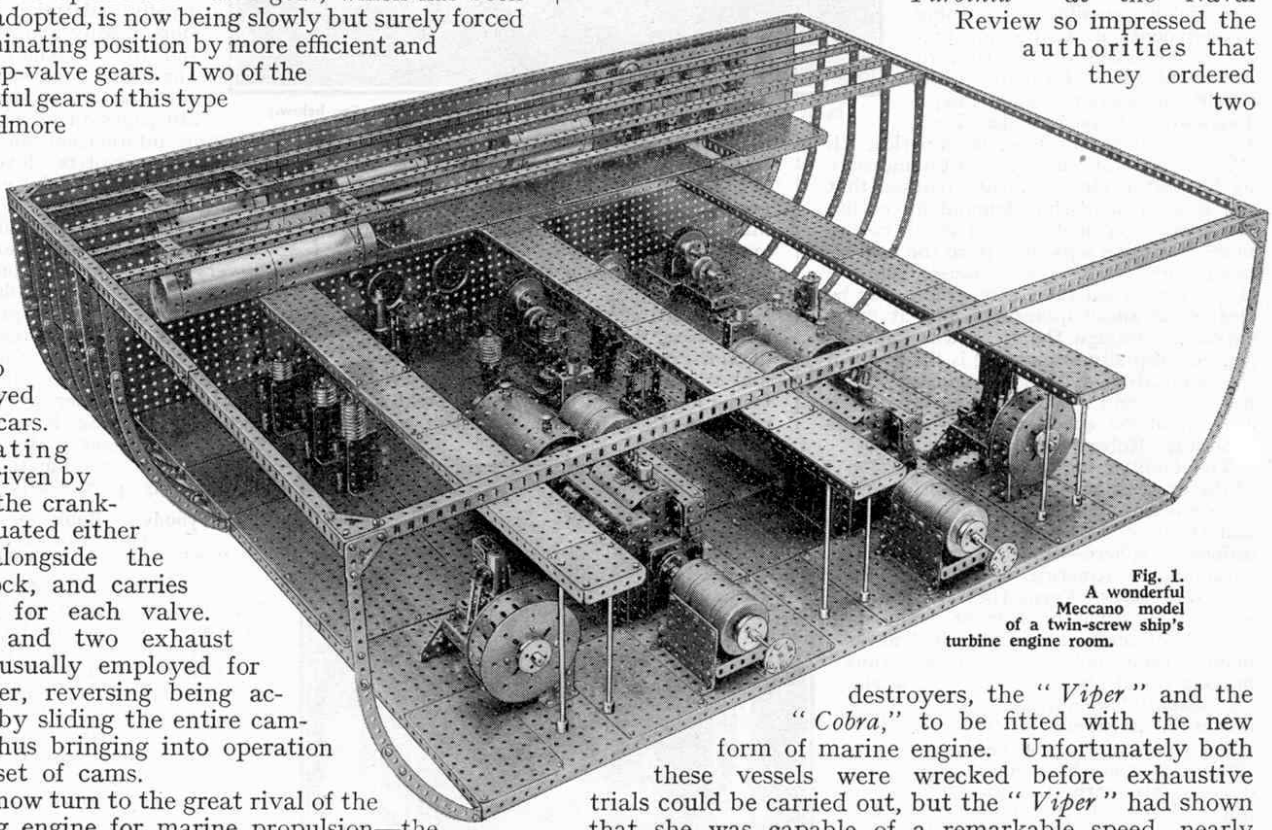

Fig. 1. A wonderful Meccano model of a twin-screw ship's turbine engine room.

The next step towards the successful adoption of the Parsons turbine came in 1901, when the Clyde passenger ship "*King Edward*" was built. This vessel was constructed to the order of a pioneer syndicate known as Turbine Steamers Ltd., which came into being as the result of the general opposition shown to the new method of propulsion by shipbuilders and shipowners alike. The "*King Edward*" was 250 ft. in length and attained a service speed of 20 knots, and it is interesting to note that she is still successfully engaged on her original service. She proved so economical and reliable in service that shipowners were forced to realise the possibilities of turbines, and within a few years almost every new fast vessel was being fitted with them.

In the mercantile marine the efficiency of the steam turbine was shown most strikingly in the struggle for speed supremacy in the Atlantic crossing. ne of the most successful and popular of these ocean greyhounds is the "*Mauretania*," which was launched in 1907, and for over 22 years outpaced all rivals. The engines of this vessel are representative of those fitted to almost all the turbine-equipped pre-war liners. Six turbines form the complete power unit, four being used for driving the vessel ahead and two for going astern; the total power output being about 80,000 S.H.P. The astern turbines rotate idly when the vessel is moving ahead, as do the ahead turbines when she is going astern.

On her early voyages the "*Mauretania*" did rather more than 24 knots, and she and her sister ship, the "*Lusitania*," were the fastest vessels on the Atlantic service. During the winter of 1909 the "*Mauretania*" was fitted with propellers of a new type that made a remarkable difference, an additional $3\frac{1}{2}$ knots being obtained. She then lowered the eastbound record with an average speed of 25.4 knots, which was increased later to 25.7 knots. As the years passed, this fine old ship, instead of decreasing in speed as might have been expected, continued to break her own records, until in 1929, when she lost the "Blue Riband" to the North German Lloyd liner "*Bremen*," she was actually running regularly at a speed of over 27 knots. This is an amazing record, and it shows in a striking manner the enormous advantages of turbines over reciprocating engines for high-speed use.

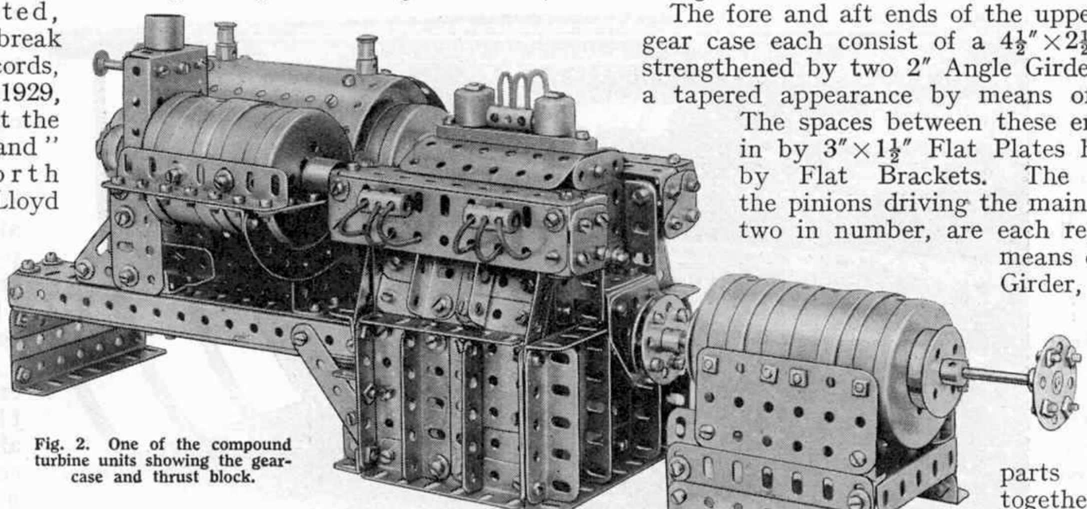

Fig. 2. One of the compound turbine units showing the gear-case and thrust block.

Up to about the year 1910 turbines were seriously handicapped in their application to slower vessels on account of their inefficiency when running at low speeds. Before this time they were always direct-coupled to the propeller shaft, and as they could not run at a speed suitable for the efficient operation of low-speed propellers, they were seldom fitted to vessels designed for a speed of less than 20 knots. In 1910, however, Parsons fitted to the steamer "*Vespasian*" a system of geared turbines that met with immediate success, and since has been used in practically every ship fitted with turbine engines. Even the fastest vessels, such as the "*Bremen*," "*Europa*" and "*Rex*," are all fitted with geared turbines, the reduction being carried out over one stage of gearing. Two stages of gearing have been tried, but the scheme was not entirely successful and has since been abandoned.

A fine Meccano model of a ship's engine room having two sets of compounded single-reduction geared turbines is shown in Fig. 1, with two sectional views in Figs. 2 and 3. It is built to an approximate scale of $\frac{3}{4}$ in. to 1 ft., and for the sake of simplicity all fittings such as ladders, gratings, steam pipes, etc., have been omitted, thus enabling the construction of the separate units to be seen more closely. It will be noticed also that a few frames and deck beams have been incorporated, these being necessary in order to support the two feed heaters shown on the left-hand side of the illustration.

One of the main propulsion motors, together with its thrust block, is shown separate from the complete model in Fig. 2. The lower half of the gear case is made in the form of a shallow box from $4\frac{1}{2}'' \times 2\frac{1}{2}''$ and $3'' \times 1\frac{1}{2}''$ Flat Plates held together by means of $2\frac{1}{2}''$ and $4\frac{1}{2}''$ Angle Girders. The forward end of the unit is fitted with an extra $4\frac{1}{2}''$ Angle Girder, and four vertical $1\frac{1}{2}''$ Angle Girders are used to act as supports below this. The $4\frac{1}{2}''$ Angle Girder carries the inner ends of four $7\frac{1}{2}''$ compound girders each of which is built up from two $7\frac{1}{2}''$ Angle Girders. The complete compound girders are then coupled together in pairs, as shown, by means of $7\frac{1}{2}''$ Flat Girders, and supported at their outer ends by a deep channel section girder formed from two $3\frac{1}{2}''$ Angle Girders and two $3'' \times 1\frac{1}{2}''$ Flat Plates. At the inner ends of the $7\frac{1}{2}''$ girders are $2''$ Strips acting as bracing members.

The fore and aft ends of the upper half of the gear case each consist of a $4\frac{1}{2}'' \times 2\frac{1}{2}''$ Flat Plate strengthened by two $2''$ Angle Girders and given a tapered appearance by means of $2\frac{1}{2}''$ Strips. The spaces between these ends are filled in by $3'' \times 1\frac{1}{2}''$ Flat Plates held in place by Flat Brackets. The casings for the pinions driving the main gear wheels, two in number, are each represented by means of a $4\frac{1}{2}''$ Flat Girder, two $4\frac{1}{2}'' \times \frac{1}{2}''$ Double Angle Strips and a $4\frac{1}{2}''$ Angle Girder, these parts being held together by Angle Brackets and small Corner Brackets. Each complete casing is secured at each end to the main gear casing by a $1'' \times 1''$ Angle Bracket. The top of the gear casing is built up from two $3'' \times 1\frac{1}{2}''$ Flat Plates surmounted by six $3''$ Strips and two Chimney Adapters. Dummy lubricators are formed from Couplings, from each of which appear three lengths of Spring Cord representing feed pipes. Copper wire is passed down the centre of the Spring Cord to hold it in position.

The low-pressure and astern turbines, both of which are incorporated in one casing, are represented by two Boilers joined together round the periphery of two $3''$ Pulleys. The bearing at the after end of this unit is built up from Sleeve Pieces, Chimney Adapters, and $\frac{3}{4}''$ Flanged Wheels, and at the forward end from a Boiler End, two Wheel Flanges and a $1\frac{1}{8}''$ Flanged Wheel. The complete unit is then secured to the $7\frac{1}{2}''$ compound girders, mentioned earlier, by two $4\frac{1}{2}'' \times 2\frac{1}{2}''$ Flat Plates and four $4\frac{1}{2}''$ Angle Girders. A support for the after bearing is also built, consisting of $1\frac{1}{2}''$ Flat Girders and Angle Girders of similar length.

The construction of the high-pressure turbine is shown in Fig. 2 and needs no further comment. It is secured in place on the inside by a $\frac{3}{8}''$ Bolt passing into the low-pressure casing, and at the outside as shown, by a

3½" Angle Girder and two 2½" small radius Curved Strips held in place by Angle Brackets. The after end is supported by Flat Girders and Corner Brackets as shown.

The thrust block consists of a series of Wheel Flanges and Boiler Ends attached to two 3"×1½" Flat Plates as shown, the Bolts in each case first being locked to the Boiler Ends by means of Nuts. The base of the block is built up from 3½" and 2½" Angle Girders and 3½" Flat Girders. The propeller shaft is journalled inside the thrust block in the bosses of Bush Wheels, and 1⅛" Flanged Wheels secured in place on the propeller shaft hold the two end Wheel Flanges of the block in place. Flexible couplings are represented by Bush Wheels fitted with Nuts and Bolts.

At each outer side of the main turbine is a circulating pump for forcing water through the condensers, which in actual practice are situated below the main engines under the engine-room floor. Each of these pumps, which do not of course work in the model, is operated by a single cylinder vertical steam engine, the construction of which will be seen from Fig. 1.

At each inner forward corner of the main engines will be seen the extraction pumps, each of which is used for drawing up the fuel oil from the ship's double bottom where it is stored, and delivering it to the boilers. A little further forward are situated three vertical pumps. These are the forced-lubrication pumps, and in an actual vessel of this size two are always kept working when the main engines are in operation, with one always in reserve. Three similar pumps will be found on the port-hand side of the engine-room. The two forward ones are the sanitary and bilge pumps, while the other, that is fitted with an extra large cylinder, is the emergency bilge and ballast pump. Two further pumps also are incorporated, these being the main boiler feed pump and the fresh water pump. The first-named is shown in Fig. 3, and the other is situated on the starboard-hand side of that main engine.

The primary and secondary feed heaters are represented by Boilers as shown, and are suspended from the main-deck beams at the forward end of the model. Two further Boilers also are fitted, and are secured to the forward bulkhead. They represent the two oil-coolers through which the hot lubricating oil from the entire engine room passes in order to be reduced to a suitable working temperature before being re-delivered to the various working parts.

Fig. 3 shows the arrangement of the fitting at the forward bulkhead. The starting platform is seen on the left-hand side, the three turbo-generators are on the right, and above these is the main switchboard. Below the main switchboard a platform running the entire breadth of the ship is fitted and, as will be seen from Fig. 1, three others branch off from this. These are supported at their after ends by 6½" Rods and Rod Sockets.

From this model and the foregoing description some idea of the complication and magnitude of a modern ship's engine-room will be gained, but only an actual visit could possibly convey the idea of pent up energy so characteristic of the modern ship. In the model there appears to be considerable space between the various units, but in actual practice this is far from being the case, for almost every available square foot of floor and wall space is taken up by pumps, too small to show in this model, pipes, ladders, wires, lamps, tool racks and a hundred and one other items, all of which go to make a ship's engine room one of the marvels of modern engineering.

It is an interesting fact that the two rivals, the reciprocating engine and the steam turbine, can be used together. The usual arrangement consists of an exhaust steam turbine coupled in tandem with the main reciprocating engine. The turbine extracts almost the last particle of energy from the steam coming from the main engine, and thus brings about greater economy. It is necessary that the turbine should be designed so that its speed is practically identical with that of the main engine, for otherwise it would cause this engine to drag. In some cases the turbine is not placed in tandem with the main engine, but is arranged to drive an electric generator that in turn supplies the necessary current for operating a powerful motor placed between the main engine and the propeller. This arrangement is said to be very efficient, but the high initial cost of the necessary installation is a drawback to its widespread adoption.

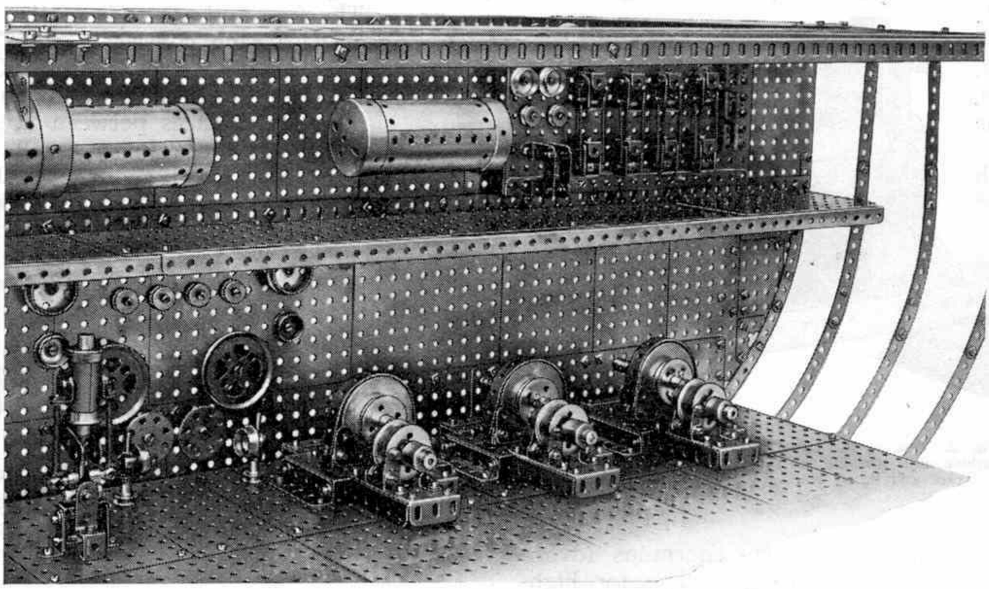

Fig. 3. The generating flat and control platform, the main switch-board being seen immediately above the dynamos.

A still more recent innovation is the turbo-electric system of marine propulsion, in which the turbines drive large electric generators, and the current from these operates powerful motors coupled direct to the propeller shafts and placed in the very stern of the ship so fitted. Remarkable ease in manœuvring is claimed for this method, and it also lends itself readily to considerable economy when running at low speeds. Although economical in operation, it is costly to install, and its use therefore is limited to the bigger class of ships.

Next month we shall complete this series of articles on marine engine history with a number of models of Diesel engines.

British Marine Engine History in Meccano

VI.—Modern Heavy Oil Engines

As shown in last month's *"Meccano Magazine,"* turbines have largely replaced reciprocating engines as the means of propelling ships. A serious competitor to both types of steam engines has now made its appearance, for recent years have seen the introduction and development of an entirely new type of marine motive power. This is the heavy oil engine, the pioneer of which was Dr. Rudolf Diesel, an engineer who was born in Paris and trained at the Munich Polytechnic. Early in his career Diesel was impressed by the low efficiency of the steam engine, and after experiments with an engine employing coal dust as fuel he took out in 1892 a patent for an engine utilising crude oil. Three years later he produced his first successful engine. Improvements followed rapidly, the original engine being greatly modified, and the Diesel engine in its various forms eventually became a formidable competitor of the steam turbine and reciprocating engine. Diesel disappeared at sea in 1913 while on a voyage to England, and his mysterious death prevented him from seeing the triumph of the heavy oil engine.

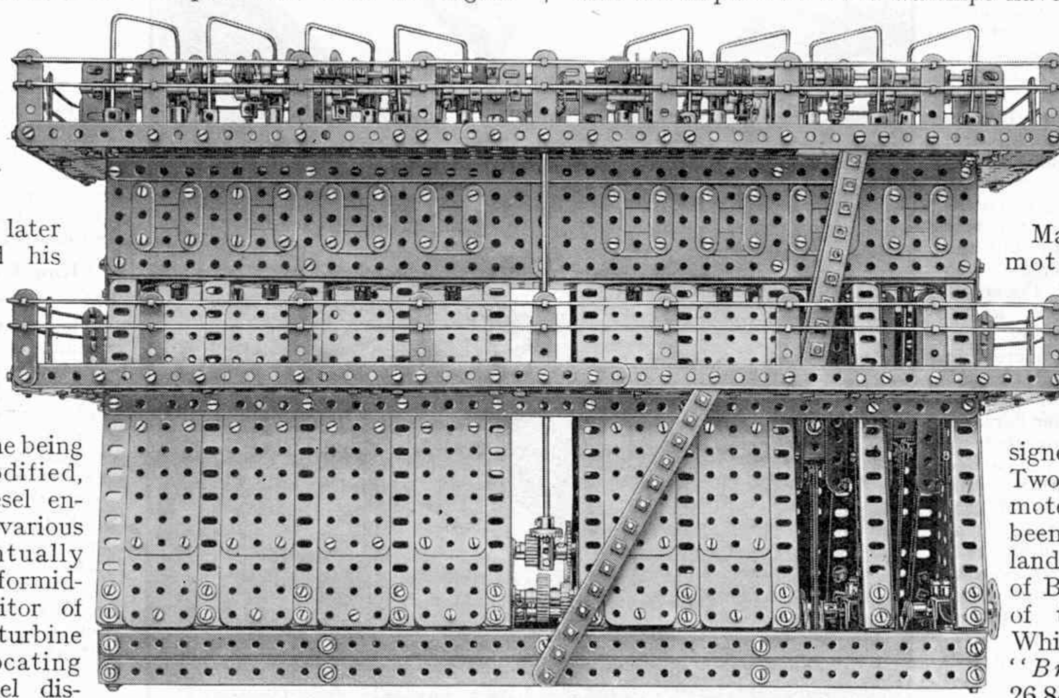

Fig. 1. A fine model of an M.A.N. eight cylinder, airless injection, heavy oil engine.

Early marine engines of the internal combustion type used different types of fuels, but it was soon realised that for general use the residue from refined petrol was the most advantageous. The fuel is now generally known as crude oil, and engines using it differ in many respects from internal combustion engines employing petrol. The chief difference is that the mixture injected into the cylinders is not ignited by means of an electric spark; instead its temperature is raised to ignition point by the heat developed during the compression stroke. The absence of an ignition system is one of the chief reasons for the popularity of the heavy oil engine and in addition the possibilities of fire are reduced to a minimum, since in normal circumstances, the fuel used is not inflammable.

Although the installation of a heavy oil engine in a ship is usually more costly than that of a steam engine, whether of the turbine or reciprocating type, the extra initial outlay is more than recovered in savings on running costs, for smaller engine room staffs are required, and other expenses are reduced. In addition less space has to be allotted to the fuel than would be needed in a steamship for coal or oil fuel, and a motor vessel therefore can be given a remarkably large cruising radius. This is of special value in the case of warships. Many remarkable voyages have been made of recent years by the German vessels, the light cruiser *"Karlsruhe,"* and the pocket battleship, *"Deutschland,"* both motor vessels, and the impression these warships have made is being shown by the interest taken in their performances in many maritime countries.

Many remarkable motor ships for mercantile purposes also have given great satisfaction to the designers and owners. Two famous British motor vessels have been built by Harland and Wolff Ltd. of Belfast. The first of these was the White Star liner, *"Britannic,"* of 26,840 tons, the construction of which was closely followed by that of her sister ship, the 27,759 ton *"Georgic."* Both vessels have been running for several years on the regular trans-Atlantic service and also on pleasure cruises. They are exceptionally good sea boats, and have shown marked efficiency.

Heavy oil engines for ocean-going vessels have been developed so rapidly that it is difficult to follow the stages through which they have passed. The tendency has been in the direction of six or more cylinders, as many as 10 or 12 being commonly used for large vessels in which freedom from vibration is of major importance. A fine Meccano model of a multi-cylinder crude oil engine is illustrated in Figs. 1 and 2. This model is a scale reproduction of an M.A.N. eight cylinder airless injection, four stroke cycle engine, developing over 3,000 B.H.P. In an engine of this type the fuel from the main tanks is injected into the cylinders by means of a force pump. It passes through fine nozzles, and as it enters the cylinders is mixed with air passed through a separate valve and compressed by the piston until it reaches a high temperature. This is not in accordance with general crude oil engine practice, the usual method being to force the fuel into the cylinder by compressed air. In the model the pipes taking the fuel from the control valves to the cylinder heads are seen above the valve gear.

The base of the model is constructed from 18½″ Angle Girders and 4½″ Angle Girders, Flat Girders being used as shown in order to give depth to the base. At the point where the long Girders forming the sides of the base are secured to the shorter Girders representing the ends, 1″ Corner Brackets are used for strengthening purposes. At intervals of 2½″ eight pairs of 4½″ Angle Girders are fitted to carry the main crankshaft bearings.

As shown in Fig. 1, each bearing is represented by two 1½″ Flat Girders and two Angle Girders of similar length, the Angle Girders being fitted with ½″ × ½″ Angle Brackets and Collars in order to give the effect of a plumber block. The construction of the crankshaft is similar throughout its entire length to the portion shown in Fig. 1, the two side plates of the engine at this point being removed in order to show the internal construction. The space between the two centre bearings of the engine is fitted with a 1″ Gear that meshes with a similar gear carried on a 2″ Rod and journalled in two 1½″ Flat Girders. The Rod carrying this second 1″ Gear also supports a ¾″ Pinion that is in engagement with a 50-teeth Gear mounted on a Rod and carried in bearings as shown. A second ¾″ Pinion, driven by the 50-teeth Gear, drives a long vertical Rod that will be described later.

At similar intervals to those between the crankshaft bearings, 1″ × 1″ Angle Brackets are fitted to the base at each side, and these support the main standards supporting the cylinder block. Each standard is composed of two 7½″ Angle Girders fitted with a 4½″ × 2½″ Flat Plate. This Plate carries two 4½″ Angle Girders to form a channel in which slides one side of the corresponding crosshead, a Channel Bearing, and the standards must be secured rigidly to the 1″ × 1″ Angle Brackets already mentioned, since they are unsupported at their upper ends. Each of the end pairs of standards is fitted with a 2½″ Flat Girder by means of which the cylinder block is held in place.

The cylinder block is composed of a number of 5½″ × 2½″ and 2½″ × 2½″ Flat Plates that are held in place on a framework of 18½″ and 2½″ Angle Girders. The top of the cylinder block is not fitted until the valve gear is to be attached. The underside of this part of the model is fitted with eight Bush Wheels representing the bottom ends of the cylinders. Each of these forms a bearing for a piston rod, a 3½″ Rod, and this is secured to its crosshead by means of a Coupling, the underside of the crosshead being secured to the connecting rod by a ⅜″ Bolt, and two ½″ × ½″ Angle Brackets. The lower end of the connecting rod is carried on a ¾″ Bolt forming the connection between the two crank webs. Great care must be exercised in "lining up" the various bearings, especially the crankshaft bearings, for the connections between the crank webs are liable to work loose if these are not correctly fitted.

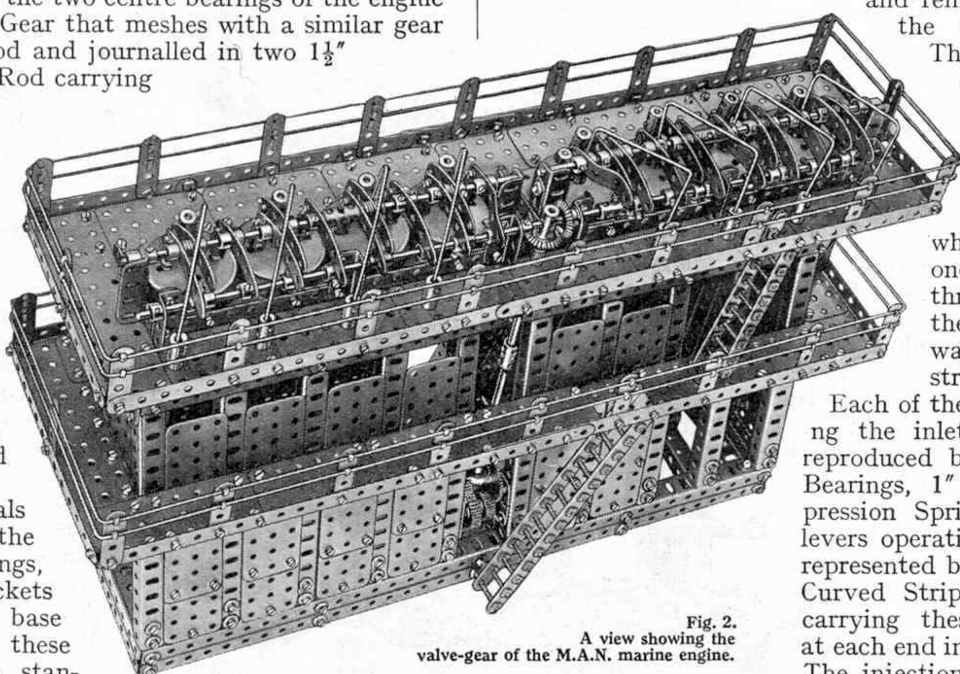

Fig. 2.
A view showing the valve-gear of the M.A.N. marine engine.

The general appearance and construction of the catwalks round the engine will be seen on reference to Figs. 1 and 2. The ladders communicating with these walks are constructed from Strips of suitable lengths and 1″ Threaded Rods held in place by locknuts. Handrails are represented by lengths of Spring Cord held in place by Dredger Bucket Clips.

The valve gear is shown in detail in Fig. 2. The camshaft is journalled in the upper holes of six bearings formed from 1½″ Angle Girders and Simple Bell Cranks. The cams are formed from Collars and Bolts and the timing of these for each cylinder must be carefully adjusted. The inlet valve, which is the first on the left of each cylinder head, opens as the piston descends during the inlet stroke. The valve then closes, and all three valves are closed as the piston ascends to effect compression and remain closed during the explosion stroke. The exhaust valve opens as the piston ascends for the exhaust stroke, and the scavenger valve, which is the middle one of the set of three, opens when the piston is halfway through this stroke.

Each of the valves representing the inlet and exhaust is reproduced by means of End Bearings, 1″ Rods and Compression Springs. The rocking levers operating the valves are represented by 2½″ large radius Curved Strips, and the Rods carrying these are supported at each end in 2″ Angle Girders. The injection pipes are shown in the illustration, from which the method of operating the camshaft will be gathered.

Among the modified and improved forms of heavy oil engines none have been quite so conspicuous as those introduced by William Doxford & Sons Ltd., whose works at Sunderland have produced some of the most remarkable heavy oil engines known. These engines employ two pistons in each cylinder that travel in opposite directions. They are coupled to the crankshaft by a system of three cranks per cylinder, the upper piston being coupled by two long connecting rods. Thus work is recovered that in an engine of normal type is lost owing to the expansion of the hot gases against the cylinder head. Water cooling is employed for the cylinder walls and the piston rod glands, the water being delivered to the upper piston rod by means of lengths of armoured hose.

The most recent Doxford engine has four cylinders arranged in separate pairs. It develops 3,300 I.H.P. when running at 92 r.p.m., and for its weight and size is a remarkably powerful and economic power unit. One of its most outstanding features is its comparatively small weight, for this has been reduced considerably by the adoption of electrically-welded construction for the engine framings.

The Meccano model shown in Figs 3 and 4 is a scale reproduction of this remarkable unit, and embodies all the main characteristics of the prototype. The lower portion of the frame consists of a rectangular base built up from $18\frac{1}{2}''$ and $7\frac{1}{2}''$ Angle Girders, the vertical members being composed of $9\frac{1}{2}''$ Angle Girders. The plating of the sides and ends is accomplished by means of $5\frac{1}{2}'' \times 3\frac{1}{2}''$ Flat Plates and other Plates of various sizes. Inspection covers are represented by Face Plates, those fitted to the upper set of removable side plates being detachable, together with the sections of the model to which they are fitted. A platform is constructed round the entire engine at the top of the $9\frac{1}{2}''$ vertical members already mentioned. It is built up of Flat Plates braced underneath by means of $5\frac{1}{2}''$ and $4\frac{1}{2}''$ Strips held in place by means of Angle Brackets.

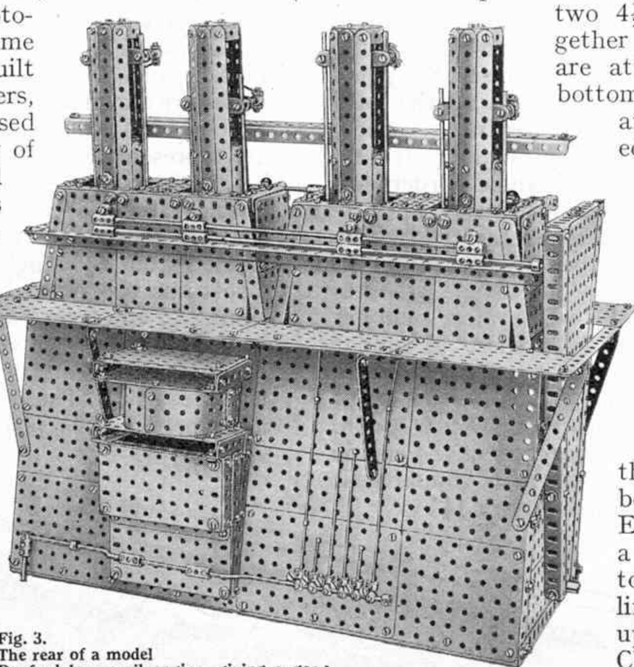

Fig. 3.
The rear of a model Doxford heavy oil engine, giving a good impression of the clean finish to an engine of this type.

Each pair of cylinders is set in a block secured to the top of the lower engine framework, as shown, and each cylinder is built up from $9\frac{1}{2}''$ and $5\frac{1}{2}''$ Strips bolted round the outside of $4\frac{1}{2}''$ Strips bent to the required shape. The two pistons in each cylinder slide in the bosses of Bush Wheels and are coupled up as shown by those sections of the engine framework that have been omitted. The main crankshaft bearings are built up from $2\frac{1}{2}'' \times 2\frac{1}{2}''$ Flat Plates secured to $7\frac{1}{2}''$ Angle Girders and each is made sufficiently wide by spacing the two Plates used in its construction by means of Double Brackets.

The construction of the dummy valve gear on both sides of the engine is made clear in the two illustrations, and the drive for this gear is transmitted from a $\frac{3}{4}''$ Sprocket Wheel on the crankshaft to two similar Sprockets, one on each side of the engine, by means of a length of Sprocket Chain that passes completely round the three Sprockets. The armoured hose directing the cooling water to the upper cylinders is represented by lengths of Spring Cord, the various fittings used in conjunction with this Spring Cord being constructed as shown.

Fig. 4.
The Doxford engine from the control side, showing some of the cranks and connecting rods.

The rear of the engine is fitted with a large pump, the movement of the piston of which is taken from one of the two centre sets of cross-heads by means of two $2''$ Strips carried on a $4\frac{1}{2}''$ Rod. This Rod is secured to the two outer cross-heads of that set by means of two Cranked Bent Strips. The $2''$ Strips are pivotally attached to two $5\frac{1}{2}''$ Strips that are carried on a $5''$ Rod and connected to the pump piston by a $4\frac{1}{2}''$ Rod.

The lower portion of the pump casing is built up from two $4\frac{1}{2}'' \times 2\frac{1}{2}''$ Flat Plates held together by $4\frac{1}{2}''$ Angle Girders. These are attached to the model at the bottom by two $\frac{1}{2}'' \times \frac{1}{2}''$ Angle Brackets and the spaces between the edges of the Plates and the side of the engine are filled in by Strips of suitable length. The pump proper is set between inflow and outflow pipes, as illustrated, these in actual practice conveying the cooling water and air to and from the pump. A pipe consisting of a large Crank Handle and a small one and a $2\frac{1}{2}''$ Rod crosses the lower portion of the pump, a number of branches being taken from this as shown. Each branch is represented by a length of Spring Cord secured to the pipe by a Handrail Coupling and held in place at its upper end by a Dredger Bucket Clip. The various pieces of the pipe already mentioned are secured together by Couplings, these being attached to the engine by Set Screws.

The indicator panel is situated, for convenience, immediately above the control levers, the various small dials being represented by Bolts and Washers. One large dial at the bottom of the panel consists of a $\frac{1}{2}''$ loose Pulley. The panel is built up from two large Corner Brackets and a $2\frac{1}{2}''$ small radius Curved Strip, the edge of the complete fitting being composed of Strips of various lengths.

We have now come to the end of the story of the growth of the marine engine. Modern engines of all types are remarkably efficient, but there is still scope for much improvement and invention. Time alone will show in which direction further development will take place, but there seems little doubt that in a few years some form of internal combustion turbine will be introduced. Many inventors are now hard at work on the problems involved in the construction of a satisfactory form of this type of engine, in which the crankshaft will be given a continuous torque instead of being subjected to violent impulses at intervals, as in the ordinary type of internal combustion engine. Success in these efforts would greatly strengthen the position of the heavy oil engine.