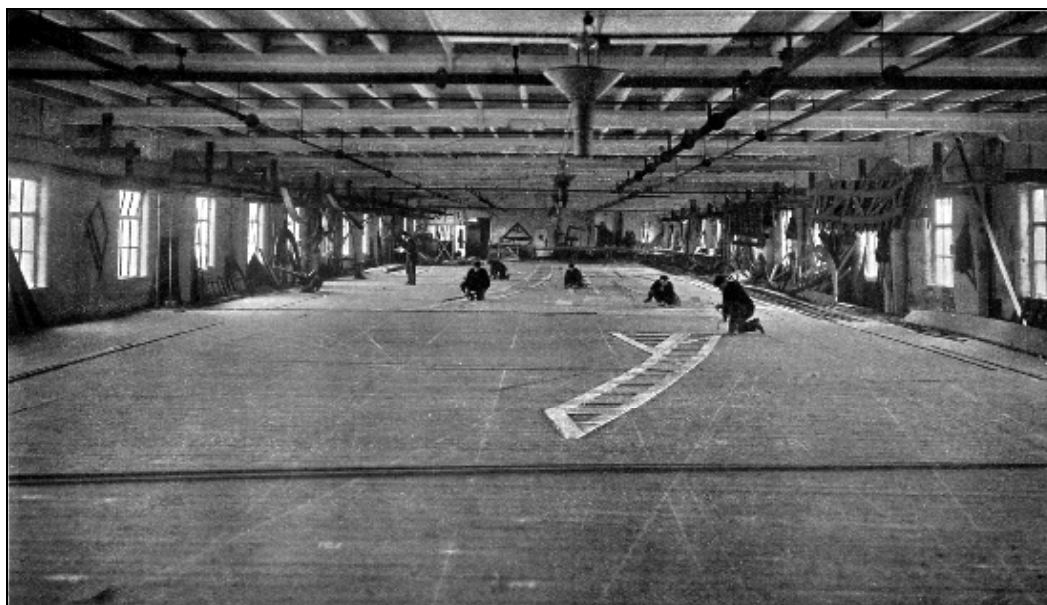


The Shipbuilding Yard

Covering an area of 40 acres, the Works have ten berths for the construction of ships of all sizes, with departments for producing all the accessories and machinery—engine and boiler works, steam-turbine factory, foundries, brass, copper, and sheet-iron shops, saw-mill and extensive wood-working department— and these give employment to four thousand workmen. The equipment has been greatly extended and modernised during the past few years. The building of the China Steam Navigation Company's steamer Fengtien in nineteen weeks, from the laying of the keel to the trials, is one of several instances of rapid construction which might be enumerated.

The plans of ships prepared in the designing department and drawing offices, to which reference has been made in the previous Chapter, are passed to the moulding loft, where the work of construction is commenced. This loft is situated in a substantial four-storey building, accommodating practically all the wood-finishing departments. Each floor has an area of 12,500 square feet; the ground and first floors are given up to the joiners and cabinet-makers, with their numerous machine tools, while the top floor is at present utilised for storing completed joiner work, etc.



The Moulding Loft

The Moulding Loft monopolises the third floor, and as the length is 240 ft. and the width 52 ft., there is ample space, as is shown above, for laying down full size deck-plating, stringers, margin plates, deck girders, etc., so that moulds or templates may be prepared for the iron workers. Armour-plates for warship belts, barbettes, and casemates are similarly prepared in template, to assist the makers to form them to the required curvature and size.

The ironworkers' department is extensive and important. When the material is delivered into the yard, it is discharged from the railway wagons by a 5-ton electric overhead travelling high-speed crane, which stacks the plates and bars in such a way that any piece can be readily removed by the same crane for conveyance to the furnaces.

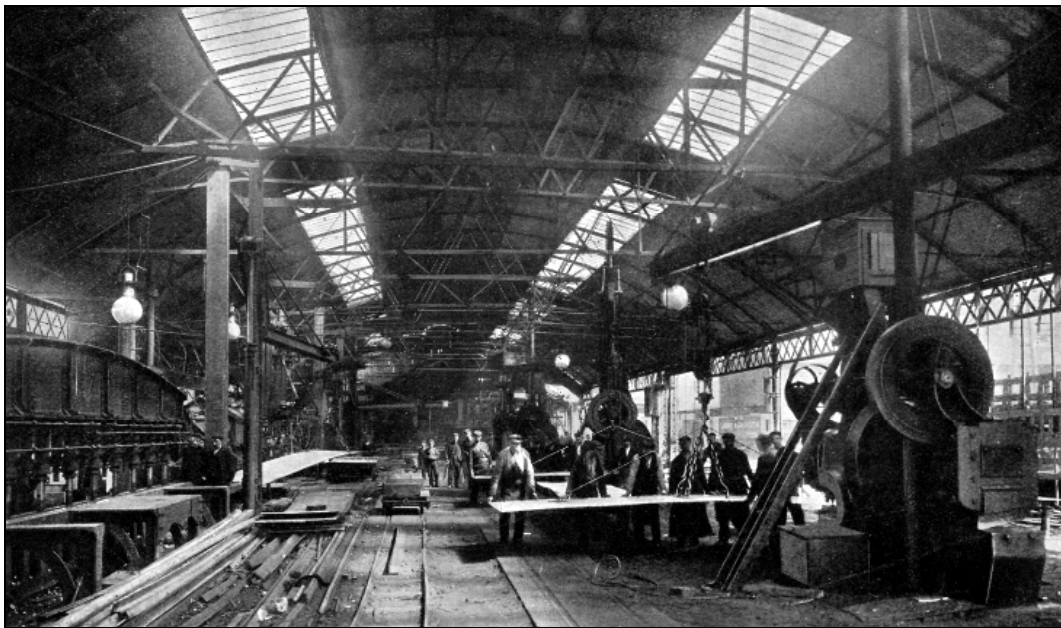
There are six furnaces suitable for heating shell plates of the largest size, and angles and bars for frames, etc., up to 60 ft. in length. Adjacent to the furnaces are the screeve boards and the frame-bending blocks. The channel, bulb angle, or Z bars, used so extensively now for framing in large ships, are bevelled as they pass from the furnace to the bending blocks. This is done in a special machine made by Messrs. Davis and Primrose, Leith. The bars, as delivered from the rolling mills, have flanges at an angle of 90 deg., which is not suitable for taking the skin plating of ships. One angle has therefore to be altered, so that while the inner flange may lie at right angles to the

keel-plate, that to the outside will fit closely to the shell plating throughout the entire length of the frame from keel to shear stroke, which may be 50 ft. or 60 ft.

As the bar passes through the machine, the web is carried on an ordinary flat roller, while bevelling rolls, set to the desired angle, work on each side of one of the flanges to give it the desired set. There are several of these machines in use, and they run on rails laid across the front of the furnace, so that the angles, Z sections, or channels may be bevelled while passing out of the furnace on to the bending blocks. The manipulation of the plates from the furnace is by means of steam and electric winches.

Formerly, the turning of the frames to the required curvature against the pins on the bending blocks was carried out by hand. To suit the heavier scantlings of the larger ships of the present day, a portable hydraulic machine is now utilised. It is fixed at its base by pins, which fit into the ordinary holes in the blocks, and hydraulic pressure is supplied through a flexible pipe to work the ram-head against the angles, forcing them to take the desired form. The machine is a great labour economiser, as it ensures work on the heaviest of bulb angles being carried out in the minimum of time, and therefore at top heat.

The bars are usually cut to length by a guillotine, but it was considered that this tended to twist the metal, and perhaps unduly fatigue it; and as a consequence the firm have fitted John's shearing and notching machine, as constructed by Messrs. Henry Pels and Co., of Berlin. The tool is shown in the act of cutting through a channel section. The cutting tool is seen immediately in front of the operator, and is actuated by gearing accommodated within the standards of the machine. When the cutting tool is brought down on the angle or beam to be sheared, and the shaft at the rear started, the rotation of an eccentric actuated by the shaft causes the point of the tool to slide idly a short distance to-and-fro on the bar. The hand lever on the right hand side of the machine is depressed, forcing the tool downwards, and the continued rotation of the eccentric causes the tool to pierce through the bar with a downward and inward motion. Where there is a deep web with flanges, the beam is reversed on the anvil, to enable the other flange to be cut. The cutting of any bar in this machine is a matter of only a few seconds.



In one of the Platers' Sheds

Of the platers' shed, where the plates, angles, bulbs, bars, etc., are machined, a view is given above. It may be said generally that the machines are designed to deal with plates up to 50 ft. in length and with angles up to 60 ft. in length, and of corresponding sections. It follows that the straightening and bending rolls, edge-planers, and punching and shearing machines, are of great power. It is scarcely necessary to make detailed references to all of the tools for these and other purposes.

All the tools are electrically driven. The plate-flattening rolls, which have 15 and 20 horse-power reversible motors, take plates 8 ft. wide, and the rolls are from 21.5 in. to 19 in. in diameter. The bending rolls are driven by a 20 horsepower motor. The plate-edge planers, shown to the left in the view above, are operated by 16 horse-power motors, and the plate is held on the table by means of hydraulic rams as well as screw-jacks. For drilling and countersinking plates there are several modern tools, each actuated by an independent electric motor. One of

these is a three-standard drill, to deal with plates of the largest size. The spindles have a rise and fall of 10 in., and are fitted with self-acting, as well as hand, feed, and with the usual rack arrangement for the traverse of the head. Several radial countersinking machines, with 11-ft. jibs and spindles 2.5 in. in diameter, are driven by 10 horse-power motors. There are many heavy punching and shearing machines, nearly all of them having 42-in. gaps, so that they can punch holes at any part of the widest plates. As a rule, they are arranged to punch 1.5-in. holes through 1.5 in. plates at the rate of thirty holes per minute. The shears are of corresponding power.

For dealing with angles and bars there are several interesting tools, in addition to shears and punches. Some of the shears cut 8-in. by 4-in. angles, and are driven by 10 horse-power motors. There are channel-angle shearing machines, taking work 16 in. by 6 in., and operated by hydraulic pressure. These machines are made with revolving gear to suit almost any angle of flange.

There is also an hydraulic stamping press for bending angles and tees to form knee-bars and other stiffening pieces, the cylinders being 14 in. in diameter, working at a pressure of 800 lb. per square inch, with a stroke of 18 in. The machine, which has been constructed by Sir William Arrol and Company, Limited, consists of an hydraulic cylinder mounted horizontally on a massive table. On the ram-head there are former blocks, while on the table in front there are corresponding dies. The bar is placed on the table between the blocks and dies, and as these are forced together by hydraulic pressure, the bar between them is squeezed into the exact shape required. Not only is the operation expeditiously executed, but there is no uncertainty. The whole of the metal within the bar is retained inside the knee, which becomes thicker and broader, materially adding to its strength. As the moulds or dies can be made to suit any form, the machine can be utilised in the preparation of various details of structures, provided they are designed with a view to their production by aid of dies. The great economy resulting from the use of special machines is only realised when the designing staff remember that they must be kept employed.

An especially powerful tool is provided for bending channel irons and beams, and for drilling horizontal holes in them. Hydraulic manhole-punching and flanging machines are employed, each having a ram of 27 in. in diameter, and capable of punching a hole 42 in. by 16 in. through a plate .75 in. thick. There are provided dies for forming flanges 4 ft. 6 in. deep in the widest of plates.

The modern practice of joggling and of scarfing the laps and edges of plates is applied in many instances, and special hydraulic tools are provided to carry out this work. The firm were also early in adopting the practice of joggling frames, deck beams, etc. The frames and beams are joggled when cold, to suit each alternate inner strake of plating, in a special design of hydraulic press, of which there are several in the works. This tool carries dies on the ram-head and on the anvil, to form between them the obverse and reverse sides of the dent or joggle desired. Movable centre-pieces on the ram-head and anvil are traversed in all directions by screw thread to suit the position and width of the joggled part, and a gauge shows variations of 0.1 in. in the position of the joggled part of the frame. A 2 ft. length of angle can be joggled at each stroke. The machines are by Messrs. Hugh Smith and Co., Limited, Glasgow.

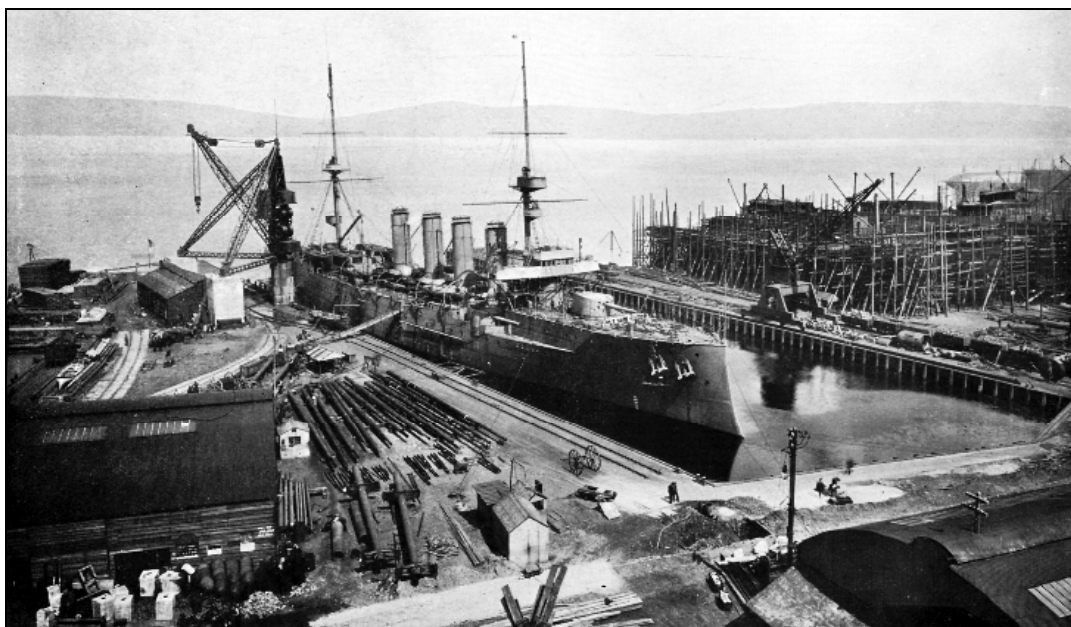
The same machine joggles the lap or edge of a shell, inner bottom, or deckplate in a similar way. The whole length of the frame or plate can thus be worked in a very short time. A powerful jib crane, of 16 ft. radius, assists materially in the rapidity of the work turned out by these tools. The only slips required are at the ends of the vessel, where the bevel of the frames precludes the use of joggling. A special electrically-driven hammer is used for forming these taper slips.

The angles, etc., to form the frames are assembled at the head of the building-berth, and when lying on skids are riveted to form the double bottom, frames and margin plates. Hydraulic riveters are used wherever possible. There are about a score of these at work in the shipbuilding yard, with cylinders from 8 in. to 10.5 in. in diameter, a stroke of 7.5 in., and a gap of 55 in., so that heavy work can be done. Some of them are specially designed for keel work, for closing rivets in beams, and for difficult parts.

The frames thus riveted are conveyed down the berth by a simple and ingenious cableway, known in the Works as the switchback, from its resemblance to the well-known amusement railway. A derrick-post stands at the head of the berth adjacent to the skids on which the frames are riveted. The cable stretches from a small derrick at the foot of the shipbuilding berth over a pulley at the top of the large derrick-post, and thence, through a similar block at its base, to an electric winch. The frame or unit of the ship's structure is suspended on a running block on the cable, which is then made taut, partly by the working of the winch and partly by the large derrick post being inclined backwards. The running block with its load travels down the taut cable by gravity, under the guidance of the squad of fitters. The gradient of the cableway is only sufficient to enable the load to move slowly to its position in the shipbuilding berth.

The double-bottom frames and margin plates are united with the keel-plate, and subsequently there are successively worked into the structure the tank top plates, side frames, the skin plates, beams, bulk-heads, and other units, portable hydraulic punches and riveters being largely used. Pneumatic tools are also extensively employed for boring, drilling, riveting, chipping, caulking, etc. There are from 130 to 140 of these tools in use on vessels in course of construction.

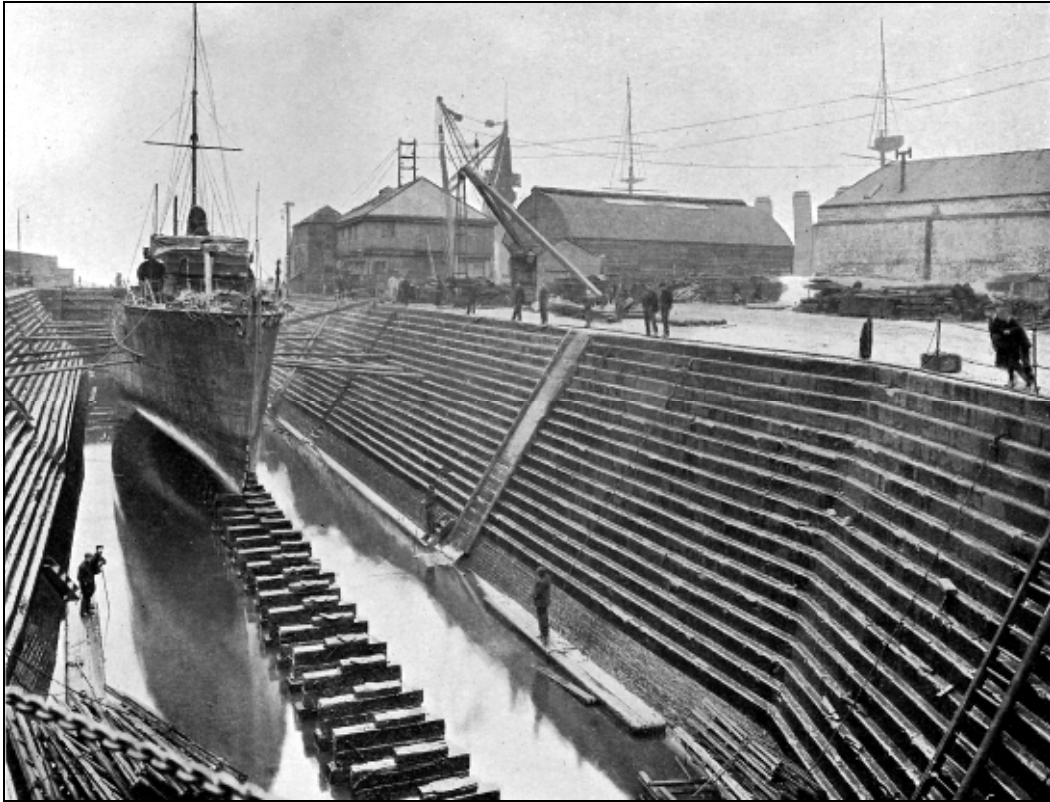
There are ten building berths ranging in length up to 700 ft.; but slight alterations would enable the firm to build vessels of still greater size. The launching ground is probably the finest in the river, the channel being here of great depth and very wide, as is shown on the engraving opposite. Indeed, ordinary merchant vessels with full lines are launched without any check chains; the fine-ended ships—mail steamers and cruisers—are, as a precautionary measure, checked by drags in the usual way.



The Fitting Out Dock

The ships launched are completed in the fitting-out dock, constructed about two years ago, and illustrated above. The engraving shows H.M.S. Argyll under the big jib-crane. This dock has a length of 560 ft. and a width of 172 ft., and opens directly into the channel of the Clyde. The depth of water is never less than 28 ft., so that warships are afloat at all states of the tide. A prominent feature in the view is the crane, which was supplied by Messrs. George Russell and Co., Limited, of Motherwell, and lifts 120 tons at a radius of 70 ft. It is carried on concrete foundations and piers, which rise 20 ft. above the level of the quay. In addition to the pier for carrying the mast of the crane, there are similar supports for each of the back legs through which the crane is anchored.

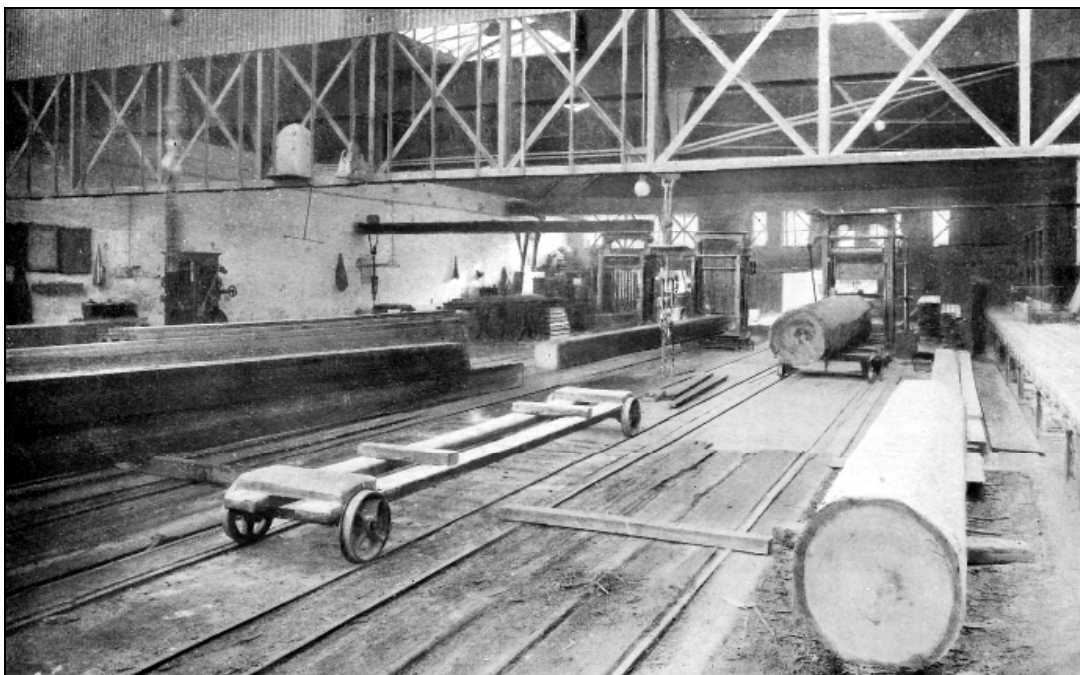
One advantage of the derrick type is that the crane may be placed close to the edge of the quay; in this case the centre is only 7 ft. from the front of the wharf, so that the full load of 120 tons can be dealt with at an effective outreach of 63 ft. from the quay. The maximum radius of the heavy purchase with a load of over 60 tons is 90 ft., and of the light purchase gear, with a load of 10 tons, 98 ft. The minimum radius of the crane is 25 ft. There are four sets of gear: for lifting heavy loads, for raising light weights, for derricking the jib, and for slewing; a separate controller of the enclosed tramway type is provided for each. The main hoisting and derricking motors are of 50 horse-power, and the others of 35 horse-power. The speed of hoisting 120 tons is 5 ft. per minute, while a 10-ton load is raised at the rate of 40 ft. per minute. Automatic brakes are fitted for the slewing motion, and powerful hand-brakes for the hoisting and derricking gears. All motions are controlled by one man in the steelhouse fixed to the mast of the crane 56 ft. above the quay level.



The Graving Dock

There is on the opposite wharf of the dock a 20-ton travelling electric crane, and throughout the Works there are many portable and hydraulic cranes, in addition to the hydraulic and other cranes commanding the machine tools. Reference may here be made to the Company's graving dock, illustrated on Plate XLV., adjoining page 101. The length is 360 ft., and it is largely used for docking ships for repair, as well as for cleaning ships preparatory to trial. Our view shows a torpedo-boat destroyer in the dock. The pumps for the emptying of the dock are electrically driven.

We may return now to our narrative of the construction of a ship, and deal with the supplementary departments, including those of joiners, smiths, plumbers, sheet-iron, and other workers.



The Saw Mill

Wood-work forms a large and important item in most of Scotts' ships, as many of them are for passenger service. We illustrate above one of the saw-mills. It is self-contained, having its own power plant, including a compound engine, having cylinders 15.25 in. and 27.5 in. in diameter by 44-in. stroke. There are four vertical saw frames, the largest having a 36-in. frame, six rollers, and two bogies to take in the heaviest logs. In addition, there are circular saws, ranging up to 6 ft. in diameter, a swing cross-cut saw, special planing, moulding, and turning machines to do heavy work, and saw-sharpeners, grindstones, punching machines and anvils to carry out all repairs and fettling of the blades, etc. There are also large steam-heated drying stoves, and a timber-drying yard of about three acres in extent. The overhead travelling cranes range up to 5 tons capacity and the rails on which they run are extended on columns across the yard. The saw-mill is the largest and best-equipped in the district, and does the sawing and planing of timber for three of the largest shipbuilding yards, as well as the general work for two other firms.

The joiners' and cabinet-makers' shop, as we have already indicated, occupies two floors of a building 240 ft. long and 52 ft. wide; while the fourth floor is utilised for the French polishing work, as well as for storing the completed wood-work until the vessel is ready to receive it. Provision is also made in the same building for the model-making department, in which replicas of nearly all ships are produced, and, being works of art, because of their completeness, accuracy, and beauty, have earned high awards at many Exhibitions.

In the joiners' shops, there is a complete equipment of wood-working machines for sawing, turning, planing, moulding, sand-papering, mortising, boring, tenoning, dovetailing, dowelling and joining. These are electrically driven, and are grouped at three places in the length of the shop on each floor, with benches around them, so that the joiners do not require to carry their jobs any distance in order to have them machined. There is also in use in connection with the department a portable electric circular saw, which is especially useful for carpenters and joiners, etc., on board the ship in the dock. An electric deck-planer, of the lawnmower form, has proved serviceable in reducing enormously the most laborious task experienced by carpenters and joiners.

There are two large smithies convenient to the shipbuilding berths, and in both cases the finishing department adjoins. In one case there are fifty-four fires and eight hammers; in the other, forty fires, with five hammers, ranging up to 15 cwt. The fires are operated by mechanical blowers, and the smoke and waste gases are carried off by overhead ventilating pipes. Extensive work is carried out by the smiths. Die-stamping is largely adopted in connection with the making of eye-plates, cleats, stanchions, clips, etc. In each finishing shop there are band saws, radial and other drills, screwing machines, and grindstones. Smiths' stores are arranged above the finishing shops. The plumbers' shop is fitted with a special machine for bending pipes when cold, as well as screwing and tapping machines, drills, saws, grinders, and fires.

The sheet-iron department is equally well equipped, having straightening rolls, shearing, punching, chipping, drilling, and other tools, with various hammers; and here work is done in connection with ventilating and other light ironwork.

In view of the warship contracts undertaken, the mechanics' shop, for work peculiar to the ship as distinct from the propeller machinery, etc., is extensive. The four lathes here range up to 27 ft. in length over all, with a 14-in. headstock and a 22-ft. bed. There is a useful shaping machine, a fair-sized planer, and several drills, all adequate for the work required, which is remarkable more, perhaps, for its great variety than for size.

All the machinery in the yard, and in several departments in the engine and boiler works, is run from one central station. The electric generators occupy one side of the power station, and the air compressors and hydraulic pumps the other. Steam at 200 lb. pressure is supplied by one marine cylindrical, and four Babcock and Wilcox water-tube, boilers, with superheater, coal conveyors, and mechanical stokers.

There are three electric generating sets, with a total capacity of 1200 kilowatts, the voltage being 240. The engines are of the high-speed, enclosed, forced lubrication, condensing type. The current is distributed from a switchboard in the power station by overhead mains, with three-way distributing panels in the various departments. The motors, of which there are about 130 in the shipbuilding department alone, are of the two- and four-pole type, partly or entirely enclosed, and mostly of 10 to 20 electric horsepower. Arc lamps are used for lighting, but the shops and offices are also illumined by 16 and 32 candle-power incandescent lamps. Plugs are arranged at various points throughout the yard for portable lights, and for connecting mains for lighting the various ships while being completed in the docks.

Hydraulic power at 800 lb. pressure is generated by two high-pressure pumps, with steam cylinders 15 in. in diameter, and rams 4 in. in diameter. There are separate accumulators for each. The pressure pipes are led underground throughout the Works to the various hydraulic tools already referred to.

There are two air compressors for supplying power for the pneumatic tools. The combined capacity is 1800 cubic feet of free air per minute. Each has two steam cylinders 6 in. in diameter, working respectively high- and low-pressure air cylinders 15.25 in. and 21.25 in. in diameter, the stroke being 18 in.

As we have already stated, part of the power generated in this station is utilised at the engine works, to which we may now turn our attention.

