ON SHIPBUILDING IN PORTSMOUTH DOCKYARD.

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Portsmouth Dockyard.—The Members of the Institution of Mechanical Engineers will find much to interest them in the Shipbuilding and Engineering departments of Portsmouth Dockyard. At the same time they cannot fail to be impressed by the fact that the establishment exists, and has its scale and character determined, by the circumstance that it has been for centuries, and still remains, our principal naval arsenal. For nearly seven centuries Portsmouth is known to have been one of the head-quarters for the national fleet. In 1212 the sheriff of the county of Southampton was ordered to enclose the King's Docks by a strong wall, and to provide suitable storehouses. A dockyard properly so-called was founded there by Henry VIII, coming next after that at Woolwich, which was closed in 1869: so that Portsmouth yard is now the oldest as well as the most important in existence. (See plans of Dockyard in Plates 32 and 33.)

Growth of Dockyard.—Like the Royal Navy itself, the yard had a modest beginning and a slow development. In 1540 the total area is said to have been about 8 acres. Until nearly the end of last century there was no basin in which ships could lie while completing or undergoing repairs; and the docking accommodation was poor. In the face of much opposition, and largely on the initiative of General Bentham, what was thought a great extension was carried out in the closing years of last century. A basin about $2\frac{1}{2}$ acres in area, and six dry docks adjoining it, were constructed; these are still in useful work. Dwarfed though they are by subsequent extensions, these additions to the dockyard were admirably conceived and

executed. Only a few years ago the "Victory," Nelson's flag-ship, was undergoing repairs in the yard, and her presence in the basin and dock gave an object-lesson on the sufficiency of the scale on which the work was done for the utmost demands thought possible a hundred years ago. To Bentham also was largely due the introduction into the dockyards of steam power and mechanical improvements of various kinds, including saw mills, metal mills, pumping appliances, &c. Other able men, amongst them the elder Brunel, aided in this movement; and the famous block-making machinery devised by Brunel dates from this period. At the end of last century the yard had an area of 90 acres, and was capable of building and repairing the largest classes of war ships. For forty years there was little change.

The development of steam propulsion for war ships necessitated the next great change during the period 1843-50. A steam factory with all proper adjuncts, including engine and boiler shops, foundries, &c., was then added to the yard. Another basin 7 acres in area, and four docks capable of receiving the largest ships of the period, were constructed. By 1850 the area of the dockyard had reached 115 acres: an increase of rather more than one hundred acres in three hundred years. So far the development of war-ship building had left the materials and structural arrangements practically the same as early in the century; and the five building slips on the harbour front were still capable of use in the construction of ships of all classes and of the largest size. In the latest of the screw line-of-battle ships a full sail-equipment was retained, and the character and arrangement of the armament were little changed from the days of sailing ships.

With the introduction of armour plating and iron hulls a new era of rapid development began. Sail power was diminished or abandoned. Greater steam power and higher speeds were introduced. The old smooth-bore guns and their simple carriages gave place to rifled guns of greater weight and power, with mountings of novel design. Ships became larger in dimensions, more complicated in structure and equipment. Auxiliary machinery of all kinds—steam, hydraulic, and electrical—was introduced,

either to perform operations formerly done by manual power, or to meet new requirements. All these and many other changes, to which reference cannot here be made, have necessitated corresponding changes in the plant and workshops of the dockyards, and have involved large expenditure.

There was a short period, from 1859 to 1869, during which Portsmouth fell behind Chatham and Pembroke in its equipment for iron shipbuilding, and in the scale of its operations. In 1869 however orders were given to lay down at Portsmouth the "Devastation" turret ship, which was the first iron-hulled armoured vessel built here. Since that date the old standing of the yard as a first-class shipbuilding establishment has been fully restored. A complete and extensive plant has been installed in convenient positions near the slips and docks where ships are built. New workshops and stores have been erected for electrical work, torpedoes and torpedo apparatus, gun mountings, &c. In short the dockyard has been made capable of meeting all requirements in the construction and equipment of ships of all sizes and classes.

Shipbuilding in Docks.—In one particular, present conditions compare unfavourably with past. Formerly there were five building slips, three of which were capable of receiving the largest class of ships then built. Now there is only one large slip suitable for building first-class armoured ships, and another suitable for ships of moderate size. On the other hand, docks are available, and are made use of for building the largest ships. The "Centurion" will be seen now building in the dock from which the "Royal Sovereign" was floated out in the presence of Her Majesty the Queen. Experience shows that, when docks are available, it is advantageous in many ways to use them for building ships. The risks and expense of launching are avoided; the work of construction is simplified, especially in dealing with heavy weights, such as armour plates; and economy is rendered possible in various directions. It is recognised of course that a plan such as this, while reasonable enough in a dockyard with ample dock accommodation, is not applicable in private establishments generally. One eminent shipbuilding firm

however works on similar lines, having the good fortune to possess docks. Alone among the contractors for the first-class battle-ships now building, Messrs. Laird of Birkenhead are constructing the "Royal Oak" in a dry dock, and will not float her out until she is far advanced towards completion, with hull armour fixed and engines erected on board.

Latest Extension.—The latest and grandest extension of the dockyard to meet the new conditions was commenced rather more than twenty-five years ago, and is now nearly completed. It includes three enclosed basins, having a total area of 50 acres, in which the largest ships can lie afloat; a tidal basin of 10 acres; five large docks, three of which are in use and two are being completed; and two entrance locks, available also as dry docks, Plate 33. The total area of the dockyard has thus been increased to nearly 300 acres. The fitting-out basin is still incomplete. Adjoining it, on Coaling Point, special machinery has been erected for the supply of coal to the fleet. Except at the period when the naval manœuvres are taking place, there may be seen in the basins a large number of vessels, constituting the fleet reserve, ready for service at short notice. Besides these vessels, there may always be seen new ships in various stages of progress; older ships undergoing repairs; and others lying in reserve, until they can be taken in hand. Moored in the harbour are many other vessels, some in commission, others in reserve. The squadron of royal yachts; the armoured ship carrying the flag of the Commander-in-Chief; the numerous gunboats, torpedo boats, and small craft, attached to the gunnery and torpedo schools; as well as the transport and store-ships, are all certain to attract attention. Amongst the reserve ships are many famous vessels, but none more beautiful or more worthy of admiration than the first sea-going ironclad, the "Warrior." The "Victory" remains to show what line-of-battle ships were a hundred years ago. Specimens of the screw three-deckers may also be seen, shorn of their masts and spars, but even thus left impressive by their height and bulk. In fact nowhere else can be seen such an epitome of the history of shipbuilding for the navy, as is constantly on view at Portsmouth.

New Construction.—This brief glance at the history of the dockyard and the range of its work has been taken, in order that a fairer appreciation may be gained of the conditions under which new construction must necessarily be carried on here. Important as this section of the work undoubtedly is at all times, and specially important as it has become in the last three or four years, it still has to be subordinated to the requirements of the fleet. Sudden and exceptional demands from the fleet in commission have to be met even in time of peace: more serious demands must be made when war is being waged. These are the conditions which necessarily govern the scale and character of the establishment: influencing largely the arrangements of workshops, plant, basins, and docks. Great as are the resources of the yard for shipbuilding, and large as are the provisions for engineering and manufactures of special kinds, these are necessarily overshadowed to some extent by arrangements growing out of fleet requirements. Unavoidable difficulties have therefore to be faced in connection with new construction, as compared with the facilities existing in private establishments of recent date, created solely for the construction of ships and machinery. When inspecting the dockyard, Members of the Institution will not fail to remember these essential differences; and they will make due allowance for its antiquity, for its gradual development, and for the enormously rapid changes in naval material and equipment during the last forty years, which have revolutionised the shipbuilding and engineering departments.

New construction falls chiefly upon the shipbuilding department of the yard, of which the Chief Constructor is the principal officer. In recent years the manufacture of new machinery and boilers for ships of the navy has been undertaken to a limited extent in the Chief Engineer's department. New engines and boilers have been made for the "Rupert" now undergoing a thorough repair, their aggregate horse-power with natural draught being 4,500. The engines and boilers for the second-class cruiser "Fox" now building at Portsmouth are also being made in the yard; they will develop 7,000 H.P. with natural draught, and 9,000 H.P. with moderate forced draught. This new course has been taken by the Admiralty

for special reasons, which have led also to a certain amount of new machinery and boilers being made at Devonport, Chatham, and Sheerness. The steam factories at the dockyards however are chiefly engaged in the repairing of machinery or boilers, and the making of new boilers. As a rule the machinery and boilers for new ships have been obtained from the leading marine engineers of the country; and this policy is still acted upon.

The engineering departments at Portsmouth and the other yards do a large amount of new work in manufacturing torpedo tubes, and special apparatus of various kinds, which in the public interest it is considered preferable not to have made by contract. Such apparatus is necessarily experimental in the earlier stages; and the bulk of this experimental work, in connection with gunnery as well as with torpedo fittings, has fallen upon Portsmouth, this port being the headquarters for the gunnery and torpedo schools of the fleet. The first electrical workshop under the Admiralty was organised in the Chief Constructor's department of Portsmouth yard, and has now grown into a large establishment of increasing importance; and all the other yards have now at work electrical departments, the staffs of which have mostly been trained at Portsmouth.

Expenditure.— Under the Naval Defence Act of 1889 the expenditure on new construction at Portsmouth, as well as at most of the other home dockyards, has been relatively increased. Large sums necessarily have to be expended also on the repairs and maintenance of the fleet, and on other services. The magnitude of the operations at Portsmouth is indicated by the following figures taken from the Navy Estimates for the current financial year 1892–93.

Estimated Expenditure.

	Labour.	Materials.	Total.
	£	£	£
New construction	255,450	184,380	439,830
Reconstruction, repairs &c. of fleet	134,150	65,750	199,900
Miscellaneous services, manufactures, work for other departments &c. }	149,110	65,390	214,500
	<u>£538,710</u>	<u>£315,520</u>	<u>£854,230</u>

It will be seen that nearly half the estimated expenditure on labour and more than half the expenditure on materials are to be devoted to new construction. At present about 7,500 men are employed in Portsmouth dockyard. About 60 per cent. of these are in the shipbuilding department under the Chief Constructor; 25 per cent. are employed under the Chief Engineer; and the remainder are distributed in other departments.

Past Shipbuilding.—In this paper it is impossible to give even a summary of past shipbuilding operations at Portsmouth. The appended Table 1 has therefore been prepared simply to illustrate what has been done during the last thirty-three years in the construction of typical ships; and it is by no means complete. A few explanatory remarks must consequently suffice.

Following the list given in Table 1, the first three vessels, "Prince of Wales," "Duncan," and "Victoria," were splendid examples of the screw line-of-battle ships, with unarmoured wood hulls, which formed the main strength of the navy when the ironclad reconstruction began. The "Victoria" was the largest three-decker launched at Portsmouth. It may be interesting to add that the cost of such a ship, including machinery, but excluding armament and ordnance stores, was about £230,000. This was about three times the cost of a 100-gun line-of-battle ship at the beginning of the century, and about twice that of the 110-gun sailing line-of-battle ships of 1840. On the other hand it is less than one-third the cost of a first-class battle-ship of the present day.

The "Royal Sovereign" of 1864 was launched in 1857 as an unarmoured line-of-battle ship. In 1862 her conversion into an armoured turret-ship of low freeboard was begun on the plans of Captain Cowper Coles, R.N. The upper works were cut down, and the weight saved in this way and by other changes was devoted to armour-plating the hull and the turrets. She was the first armoured ship produced at Portsmouth, and was tried in 1864.

The "Royal Alfred" was another converted ironclad, armed on the broadside principle, with high freeboard and good sail-power.

She was one of a considerable number of such vessels built when a resolute effort was being made to overtake the French in the iron-clad reconstruction.

The "Devastation" laid down in 1869 was the first iron-hulled armoured ship built at Portsmouth. She has other claims to notice. Originally designed as a breastwork monitor with low freeboard to the upper deck, she was altered during construction by adding light superstructures; and as completed was the pioneer of the numerous class of sea-going turret-ships with moderate freeboard and a few heavy guns, which are now on service in the navy. Sail-power was abolished; duplicate engines and twin-screws were trusted to entirely for propulsion. After nearly twenty years' service the "Devastation" may now be seen in hand at Portsmouth for a complete refit, which includes the removal of the old horizontal engines, and the boilers carrying only 30 lbs. steam-pressure, and the substitution of vertical triple-expansion engines, and boilers working at 145 lbs. pressure. The turret armament will be altered also to 10-inch 29-ton breech-loaders. In this way the steaming capability and fighting efficiency of the ship will be much increased. Her iron hull is as sound and strong as ever. The first cost of the "Devastation," excluding guns, ammunition, stores, and incidental charges, was about £360,000.

The "Shah" and "Boadicea" are unarmoured cruisers, with iron hulls wood-sheathed and coppered for service on distant stations where docking facilities do not exist. At the time of their construction they were notable for high speed, powerful armaments, and good sail-power. The "Boadicea" is still on service as flag-ship in the East Indies. The "Shah" is now at Bermuda, employed as a stationary ship. She will long be remembered for her fight with the Peruvian turret-ship "Huascar."

The "Inflexible," commenced in 1874, was the largest ironclad constructed for the navy up to that date; and her displacement was not again equalled until the construction of the "Trafalgar" in 1886-90. She is a turret-ship of moderate freeboard, and was the first of the central-citadel type. Her design grew out of the report of the Committee on Designs appointed by the Admiralty in 1871, with Lord Dufferin as chairman; and great controversy arose

respecting the arrangement of the armour. She is remarkable not only for her size, but for other qualities. Her hull carries the thickest armour of any ship in the navy; it is of iron in two thicknesses, which together make up as much as 24 inches. Her turrets carry steel-faced iron armour in two thicknesses amounting together to 17 inches; they contain four 80-ton guns, the heaviest muzzle-loaders afloat. She was the first of the battle-ships to be fitted with internal electric lighting, and with submerged tubes for discharging torpedoes. Many changes and additions were made during her construction, and she was about $7\frac{1}{2}$ years in hand, costing about £812,000, exclusive of armament and establishment charges. She played a prominent part in the bombardment of Alexandria. Having been thoroughly refitted, she is now on service in the Mediterranean.

The "Colossus" is a smaller central-citadel turret-ship, carrying modern breech-loading guns, with steel hull and steel-faced iron armour. Her capabilities as a steamer are much superior to those of the "Inflexible;" but in thickness of armour and weight of armament she is inferior to the larger ship. She is now in the Mediterranean on active service. Her first cost on the same basis as for other ships was about £662,000.

The "Impérieuse" is officially classed as an armoured cruiser, although she compares favourably with many vessels ranking as battle ships in foreign fleets. She possesses high speed, and is an excellent steamer. Her bottom is sheathed with wood and copper. Her armament and armour are moderate in character. At present she is serving as flag-ship on the China station. Her first cost was £544,000.

The "Camperdown" is a barbette ship of the "Admiral" class, carrying a powerful armament, with armour of considerable thickness, but limited in area on the hull. She possesses high speed and a large coal-supply. Respecting the defensive powers of this class also there has been much debate. Apart from this feature, the class has found much favour. Three years' working in the Channel squadron has established their reputation as good steamers and excellent sea-boats, while the arrangement of the armaments is

generally approved. The heavy guns, mounted in barbettes, are carried considerably higher above water than in most turret and broadside ships. Although Portsmouth has built only the "Camperdown" of this class, three other vessels built at Pembroke—the "Collingwood," "Howe," and "Anson"—came to Portsmouth in an incomplete state, and were here made ready for service. This fact is mentioned because it illustrates a section of work on new ships, of which a large share has fallen upon Portsmouth, Pembroke yard not being equipped for finishing large ships for sea. The first cost of the "Camperdown" was about £677,000.

The "Trafalgar" and her sister ship the "Nile"—the latter having been built at Pembroke and completed at Portsmouth—are the two most powerful turret-ships afloat. They are of moderate freeboard, like the "Inflexible," but are armoured on a different principle and exceptionally well protected. The armament is very powerful, and includes not only four 67-ton guns carried in two turrets, but also six 4.7-inch quick-firing guns mounted on the broadside in a protected central battery. The "Trafalgar" has an immense advantage over preceding turret-ships in this arrangement of the auxiliary armament. She is an excellent steamer. Her keel was laid in January 1886, she was launched in September 1887, and commissioned for service in the Mediterranean in April 1890. The time occupied in her construction was much less than that spent in building the battle-ships which preceded her. The cost of construction was relatively less; excluding armament and incidental charges it amounted to about £740,000.

"Royal Sovereign."—The "Royal Sovereign" of 1892 is a very different ship in all respects from her predecessor of the same name completed in 1864. So much has of late been said and written respecting the vessel that further description of the leading features in her design is here unnecessary.* It will not be out of place

* Reference may be made to papers by the author "On the Designs for the new Battle Ships," published in the Transactions of the Institution of Naval Architects, 1889, vol. xxx, page 150; and "On the new Programme for Shipbuilding," published in the Proceedings of the Institution of Civil Engineers, 1889, vol. xcviii, page 375.

however to give a few particulars of the remarkable speed with which the work of building was carried on. Instructions to prepare to build were received on 1st May 1889. Full drawings and specifications were furnished on 3rd August. The keel was laid on 30th September 1889, by which time a large amount of preparatory work on framing &c. had been done. On 26th February 1891 the ship was floated out of the dock where she had been built, fully armoured and weighing at the time considerably over 7,000 tons. The engines and boilers were ready, and were at once put on board. By 19th April 1892 she was practically complete, and passed successively through her steam, gunnery, torpedo, and electrical trials, from that date to 22nd April. A month later she was passed into the fleet reserve as ready for commission; on 31st May she was commissioned, and on 8th June she left for Portland, carrying the flag of Vice-Admiral Fairfax in command of the Channel squadron. From the date of laying the keel to the date of commissioning, only two years and eight months elapsed. No similarly rapid construction of a modern first-class battle-ship has been achieved; and the Admiralty officially expressed their satisfaction with the conduct of all concerned.

The magnitude of the work will be better appreciated from the following figures. In the first three months after laying the keel, over 1,000 tons of structural steel &c. were worked into the ship. At the end of six months this had been increased to 2,100 tons. Twelve months from the start about 3,800 tons had been worked into the hull, exclusive of armour which alone represented about 1,400 tons; so that, inclusive of armour, a weekly addition of 100 tons weight had been averaged. Six months later, or a month after the ship was floated, the hull weights exceeded 4,600 tons, and the armour approached 2,900 tons. Two years from laying the keel these weights had become 5,300 tons in the hull, and 2,950 tons in the armour; and when the ship was finished the total weight worked in had risen to 9,800 tons, inclusive of about 3,000 tons of armour.

This rapid progress demanded the most thorough organization and strenuous effort on the part of the officers at Portsmouth. It was rendered possible by the steps taken at the Admiralty in placing

orders for materials—especially armour, propelling and other machinery, guns and gun mountings, and hydraulic apparatus—so that there should be no check to progress. Private firms entrusted with this work also deserve much credit for the manner in which, under considerable difficulties, they executed their contracts. The armour plates were ordered before any portion of the ship was to be seen. Within $4\frac{1}{2}$ months from laying the keel, and before the ship was ready to receive armour, the first plate was delivered. When she was floated out of dock nearly all the armour was in place. Messrs. Cammell spared no exertion in effecting this delivery. The machinery contractors, Messrs. Humphrys and Tennant, began delivery of the engines and boilers in November 1890, anticipating considerably their contract dates, so that their work was waiting for the ship when she was floated out. Sir W. G. Armstrong, Mitchell and Co., the designers and makers of the hydraulic gun-mountings &c. for the 67-ton guns, and of the 6-inch quick-firing guns and their mountings, gave equally early delivery, and by so doing contributed greatly to rapid completion. In short, this unprecedented feat in war-ship building was the result of careful forethought and organization, as well as of unremitting and harmonious effort on the part of all concerned.

The “Royal Sovereign” has been built with no important variation from the original design. The intentions of the design have been fulfilled or surpassed in every particular. Rapid construction moreover has been conducive to economy, and the vessel has been completed for about £35,000 within the estimate for dockyard work. The original estimate of cost, excluding guns and ammunition as well as incidental charges, was £780,000, which was subsequently raised to £790,000; and the actual cost will be under £760,000. Guns, ammunition and reserves, and the consumable stores carried, will bring the total value of the ship as she goes to sea up to a million sterling.

Ships now in progress.—The vessels now building or completing at Portsmouth include specimens of four types introduced into the navy under the Naval Defence Act of 1889. Three of these are exemplified

by vessels building in the yard; the fourth is represented by the second-class cruiser "Intrepid," built on the Clyde and now completing here for service. In Table 2 appended the principal particulars of these vessels are given, together with corresponding information for the torpedo-depôt ship "Vulcan," which was also built at Portsmouth.

"*Centurion*."—The most important ship is the "Centurion" battleship. She was laid down at the end of March 1891, and is now well advanced towards the condition for floating out, with hull-armour practically complete. Figs. 1, 2, and 7, Plates 26, 27, and 30, illustrate the general arrangements of armour, armament, &c. Her principal armament consists of four 10-inch 29-ton guns, mounted in pairs in two armoured barbettes, with large arcs of horizontal training. All these guns can be fought on either broadside. Manual power can be employed for all the operations of loading or working these guns. Steam power is also provided for training the guns and hoisting ammunition. The mountings are being made by Sir Joseph Whitworth and Co. Between the barbettes are mounted ten 4·7-inch quick-firing guns; and seventeen smaller guns, 6-pounders and 3-pounders, are also carried. There are seven stations for ejecting torpedoes; two of these are under water, four on the broadside behind light armour, and one at the stern.

A belt of armour, having a maximum thickness of 12 inches, protects the water-line region for about 200 feet of the length. This belt armour is associated with a protective deck 2 to 2½ inches in thickness; and is completed at the extremities by armoured bulkheads crossing the ship. A strong protective under-water deck runs from these bulkheads to the bow and stern respectively. Above the belt armour the broadside is protected by light armour, equivalent to a total thickness of 4 inches of steel, up to the height of the main deck, which is about 9¼ feet above water. Protection is also given to the quick-firing guns and their crews, by revolving shields or fixed casemates.

The hull is of steel, built on the system usually followed in the navy, and is minutely subdivided. Steel armour made by Messrs.

Vickers is fitted on the hull and the barbettes. Wood and copper sheathing are fitted on the bottom, to prevent fouling and consequent loss of speed after long periods afloat. The ship is thus specially adapted for service on foreign stations. She is of light draught as compared with most battle-ships of her size; and will be able to pass through the Suez Canal with a large quantity of coal on board, being in all other respects fully laden.

Relatively high speed is aimed at in the design; and larger and heavier boilers than have hitherto been fitted in battle-ships have been provided, so as to secure the maintenance of speed on long-distance steaming. The Greenock Foundry Co. are the contractors for the propelling machinery.

The estimated cost of the "Centurion," exclusive of armament and incidental charges, is about £550,000. She will probably be completed in the autumn of next year.

"Royal Arthur" and "Crescent."—The "Royal Arthur" and "Crescent" are two of the nine first-class cruisers provided for under the Naval Defence Act. In nearly all respects these vessels are similar to the "Edgar," of which the steam trials have been made most successfully, the ship realizing a maximum speed of nearly 21 knots. Like the "Centurion," these cruisers will be wood-sheathed and coppered. The "Royal Arthur" was laid down in January 1890, and is to be completed this year. The "Crescent" was begun in October 1890, and will be completed in the next financial year.

Figs. 3, 4, and 8, Plates 27, 28, and 30, illustrate the general arrangements of the "Royal Arthur." She belongs to the protective-deck type of cruiser. As indicated in the cross section, Fig. 8, the hold-spaces containing engines, boilers, magazines, &c., are covered in by a curved steel deck, having a maximum thickness of 5 inches on the slopes, and $2\frac{1}{2}$ inches on the horizontal or nearly horizontal portion. This deck runs from stem to stern, and is supplemented by coal-bunker protection. Vertical engines are fitted to drive the twin-screws; and in order to secure good working conditions for continuous steaming, the cylinders are allowed to

come above the level of the protective deck, and are furnished with special armour protection.

The armament is exceedingly powerful. It includes one 9·2-inch 22-ton gun, mounted aft on the upper deck, where it can be fought on either broadside or as a stern-chaser; and twelve 6-inch quick-firing guns, of which four are carried on the main deck, six on the upper deck, and two on the high forecastle, which stretches back more than 100 feet from the bow. Besides these there are seventeen smaller quick-firing guns, 6-pounders and 3-pounders, mounted on the decks and other stations. All these guns and their crews have protection given them either by steel shields revolving with the guns or by fixed armour.

The "Royal Arthur" and "Crescent" differ from the other first-class cruisers in the possession of the high forecastle with two 6-inch guns mounted thereon. In the other vessels there is no forecastle, the freeboard forward is about $7\frac{1}{2}$ feet less, and a single 9·2-inch gun forms the bow armament.

The estimated cost of the "Royal Arthur," exclusive of armament and incidental charges, is rather less than £350,000.

"Fox."—Another type of protected cruiser is presented in the "Fox," which is as yet in an early stage of construction. Figs. 5, 6, and 9, Plates 29 and 30, illustrate her general arrangements. In size, armament, and protection, this cruiser is much inferior to the "Royal Arthur"; the speed is about the same. The estimated cost, exclusive as in the "Royal Arthur" of armament and incidental charges, is rather more than £200,000. These vessels are of high freeboard throughout their entire length, and carry all their guns on the upper deck, at a great height above water. These features will add largely to their habitability, fighting efficiency, and power of maintaining speed in rough water. There are eight vessels of this type in hand, all to be wood-sheathed and coppered.

"Intrepid."—The "Intrepid" is a somewhat smaller type of cruiser than the "Fox," costing about 90 per cent. of the latter. In protection the two classes are identical: in armament the "Fox"

is somewhat superior. In speed the difference will be small. The most important distinction is that in the "Intrepid" a long poop and forecastle are fitted, with an upper deck or waist between them at a moderate height above water, instead of the flush upper deck of the "Fox." Twenty-one sister ships to the "Intrepid" have been built under the Naval Defence Act, and most of them are now complete. The "Latona," the leading vessel of the class, has been tried in an experimental cruise to the Mediterranean, as well as in the manœuvres of 1891, and has been most favourably reported on.

"*Vulcan*."—The "Vulcan" is a vessel quite unique in character. Her special mission is to carry eight torpedo-boats of the second class; and for this purpose she is fitted with powerful hydraulic cranes capable of lifting boats weighing 20 tons. She is equipped with a workshop containing a large amount of machinery for use in repairing torpedo-boats, torpedoes, &c. A very complete laboratory is provided on board, for use in connection with torpedo and mining operations. The ship also carries a full equipment of mines and stores; and is fitted with specimens of torpedo-ejecting apparatus both above and below water. Besides all this special equipment, she carries a fair armament of guns, including eight 4·7-inch quick-firers and twelve 3-pounders. Her vitals are defended by a strong steel deck, having a maximum thickness of 5 inches. She is in fact a lightly armed protective-deck cruiser of high speed, capable of defending herself against all but the most powerful cruisers or battle-ships; and in addition she is a torpedo-boat carrier, a floating factory, a torpedo-practice ship, and a dépôt for mining stores. Her trials at sea have been deferred in consequence of difficulties which arose in connection with leakages of boiler tubes. Experiments are now in progress in other ships, which it is hoped will enable these difficulties to be surmounted. From the steam trials already made it is certain that, if this hope is realized, the estimated maximum speed of 20 knots will be attained with ease. The cost of the "Vulcan" complete with all her special machinery, but excluding guns and incidental charges, is rather less than £340,000.

Reconstruction and Repairs.—The work of this kind now in hand at Portsmouth, which there is an opportunity of inspecting at the present time, may be illustrated by the “Devastation,” respecting which particulars have already been given, and also by the “Hercules,” the “Sultan,” and the “Rupert.” The “Hercules” is now approaching completion, having been fitted with vertical triple-expansion engines and high-pressure boilers, while her sails have been removed and rig altered. Her main armament remains unchanged; but quick-firing guns have been added, and many other changes made to increase her fighting efficiency. The “Sultan,” which is a very similar ship to the “Hercules,” ran aground at Malta, and afterwards foundered; but having been raised she was brought to England. Her repairs are to be commenced in the present year, and her refit will probably follow lines similar in many respects to those of the “Hercules.” For the “Rupert” turret-ship, built with special reference to her use as a ram, new vertical triple-expansion engines have been made in the dockyard; and in the turrets breech-loading guns are to be substituted for muzzle-loaders. These and similar works of reconstruction are bringing once more into line, with greater fighting powers, ships which have already done good service.

Although this paper has extended to considerable length, it is even now a most incomplete sketch of the work and capabilities of Portsmouth dockyard. It may however serve a useful purpose if it facilitates the inspection of the establishment on the occasion of the present meeting of the Institution. In the published Proceedings also it may have some permanent interest as a record, however imperfect, of the shipbuilding operations carried out in England's greatest naval arsenal.

TABLES 1 AND 2.

TABLE 1.

Particulars of typical Ships built

Name of Ship.	Dates of Commencement and Completion.	Material of Hull.	Class.	Length.	Breadth.	Displacement.
				Ft. Ins.	Ft. Ins.	Tons.
Prince of Wales	{ ——— 4 Dec. 61	Wood	1st-rate screw Battle-ship (3 decker)	252 0	60 2	6,900
Duncan	{ ——— 1 Feb. 64	Wood	2nd-rate screw Battle-ship (2 decker)	252 0	58 1	4,555
Victoria	{ ——— 24 Oct. 64	Wood	1st-rate screw Battle-ship (3 decker)	260 0	60 1	6,960
Royal Sovereign	{ ——— Aug. 64	Wood, iron-cased	4th-rate screw Turret-ship	240 7	62 2	4,965
Royal Alfred	{ 1 Dec. 59 22 Mar. 67	Wood, iron-cased	3rd-rate screw Battle-ship.	273 0	58 7	6,720
Devastation	{ 12 Nov. 69 19 Apl. 73	Iron	Twin-screw armoured 2nd-class Battle-ship.	285 0	62 3	9,330
Shah	{ 8 Aug. 70 8 Dec. 76	Iron, wood-sheathed	Screw 2nd-class Cruiser	334 8	52 0	6,250
Bondicea	{ 20 Jan. 73 22 May 77	Do.	Do.	280 0	45 0	4,140
Inflexible	{ 24 Feb. 74 18 Oct. 81	Iron	Twin-screw armoured 2nd-class Battle-ship	320 0	75 0	11,880
Colossus	{ 5 June 79 31 Oct. 85	Steel	Do.	325 0	68 0	9,420
Impérieuse	{ 10 Aug. 81 7 Sep. 86	Steel	Twin-screw armoured 1st-class Cruiser.	315 0	62 1	8,400
Camperdown	{ 18 Dec. 82 2 Aug. 89	Steel	Twin-screw armoured 1st-class Battle-ship	330 0	68 6	10,600
Trafalgar	{ 18 Jan. 86 26 Apl. 90	Steel	Do.	345 0	73 0	11,940
Royal Sovereign	{ 30 Sep. 89 31 May 92	Steel	Do.	380 0	75 0	14,150

at Portsmouth Dockyard 1859 to 1892.

TABLE 1.

Indicated Horse-Power.	Speed.	ARMAMENT.		ARMOUR.	
		Number and Description of Guns.		Maximum Thickness.	
		Pr. = Pounder. Q.F. = Quick-firing. M.L.R. = Muzzle-loading, rifled. B.L.R. = Breech-loading, rifled.		Hull.	Turrets or Barbettes.
I.H.P.	Knots.	Number.	Description.	Inches.	Inches.
3,352	12	115	{ 1 110-pr. Armstrong 82 cwts. 10 40-pr. " 35 " 16 8-inch 65 cwts. M.L. 68 32-pr. 58 " M.L.	Nil.	Nil.
2,826	12½	81	{ 1 110-pr. Armstrong 82 cwts. 12 40-pr. " 35 " 34 8-inch 65 cwts. M.L. 34 32-pr. 58 " M.L.	Do.	Do.
4,200	12¼	102	{ 2 110-pr. Armstrong 82 cwts. 10 40-pr. " 35 " 60 8-inch 65 cwts. M.L. 30 32-pr. 58 " M.L.	Do.	Do.
2,460	11	5	9-inch 12 tons M.L.R. in four turrets	5½ inches iron	{ 10 inches iron in 2 thicknesses
3,430	12¼	18	{ 10 9-inch 12 tons M.L.R. 8 7-inch 6½ " M.L.R.	6 inches iron	Nil.
10,000	13¾	4	12-inch 35 tons M.L.R.	12 inches iron	{ 14 inches iron in 2 thicknesses
7,480	16½	26	{ 2 9-inch 12 tons M.L.R. 16 7-inch 6½ " M.L.R. 8 64-pr. 71 cwts. M.L.R.	Nil.	Nil.
5,130	14½	14	{ 12 7-inch 6½ tons M.L.R. 2 64-pr. 71 cwts. M.L.R.	Do.	Do.
8,010	13¾	12	{ 4 16-inch 80 tons M.L.R. 8 4-inch 13 cwts. B.L.R.	24 inches iron in 2 thicknesses	{ 9 inches outside, steel-faced; 8 ins. inside, iron
7,500	15½	9	{ 4 12-inch 43 tons B.L.R. 5 6-inch 5 tons B.L.R.	{ 18 inches, steel-faced }	{ 16 inches, steel-faced }
10,000	17	14	{ 4 9·2-inch 24 tons B.L.R. 10 6-inch 5 tons B.L.R.	{ 10 inches, steel-faced }	{ 8 inches, steel-faced }
11,500	16¾	10	{ 4 13·5-inch 67 tons B.L.R. 6 6-inch 5 tons B.L.R.	{ 18 inches, steel-faced }	{ 14 inches, steel-faced }
12,000	16¾	10	{ 4 13·5-inch 67 tons B.L.R. 6 4 7-inch 2 tons B.L.R., Q.F.	{ 20 inches, steel-faced }	{ 18 inches, steel-faced }
13,000	18	14	{ 4 13·5-inch 67 tons B.L.R. 10 6-inch 6½ tons B.L.R., Q.F.	{ 18 inches, steel-faced }	{ 17 inches, steel-faced }

TABLE 2.

Particulars of Ships building or

Name of Ship.	Date of Commence-ment.	Material of Hull.	Class.	Length.	Breadth.	Displacement.
				Ft. Ins.	Ft. Ins.	Tons.
Centurion	30 Mar. 91	Steel, wood-sheathed	Twin-screw armoured 1st-class Battle-ship	360 0	70 0	10,500
Royal Arthur }	20 Jan. 90	Steel, wood-sheathed	Twin-screw 1st-class Cruisers	360 0	61 0	7,700
Crescent	30 Oct. 90					
Fox	11. Jan. 92	Steel, wood-sheathed	Twin-screw 2nd-class Cruiser	320 0	49 6	4,360
Vulcan	18 Jan. 88	Steel	Twin-screw Torpedo-depôt ship	350 0	58 0	6,620
Intrepid	6 Sep. 89	Steel, wood-sheathed	Twin-screw 2nd-class Cruisers	300 0	43 8	3,600
Indefatigable }	6 Sep. 89					

completing at Portsmouth in June 1892.

TABLE 2.

Indicated Horse-Power.	Speed.	ARMAMENT.		ARMOUR.	
		Number and Description of Guns.		Maximum Thickness.	
		Q.F. = Quick-firing. B.L.R. = Breech-loading, rifled.		Hull.	Turrets or Barbettes.
I.H.P.	Knots.	Number.	Description.	Inches.	Inches.
13,000	18½	14 { 4 10 }	10-inch 29 tons B.L.R. 4·7 inch 2 „ B.L.R., Q.F. }	12 inches steel	9 inches steel
12,000	19½	13 { 1 12 }	9·2-inch 22 tons B.L.R. 6-inch 6½ tons B.L.R., Q.F. }	{ 6 ins. protecting cylinders, steel-faced ; 5 ins. deck, steel }	Nil.
9,000	19½	10 { 2 8 }	6-inch 6½ tons B.L.R., Q.F. 4·7-inch 2 „ B.L.R., Q.F. }	{ 5 ins. protecting cylinders, steel-faced ; 2 ins. deck, steel }	Do.
12,000	20	8	4·7-inch 2 tons B.L.R., Q.F.	{ 6 ins. protecting cylinders, steel-faced ; 5 ins. deck, steel }	Do.
9,000	19¾	8 { 2 6 }	6-inch 5 tons B.L.R. 4·7-inch 2 tons B.L.R., Q.F. }	{ 5 ins. protecting cylinders, steel-faced ; 2 ins. deck, steel }	Do.

Discussion.

Mr. WHITE said the purpose of the paper was expressed in its concluding paragraph. He had feared lest the members of the Institution in passing through the dockyard, unless they had something in the nature of a guide, might fail to realise the great diversity and extent of the operations there carried on, because of the very magnificence of the establishment. It had also occurred to him that many members who could not be present might be glad to have some account of what would be seen in the visit to the dockyard this afternoon under the guidance of Admiral Fane and the officers of the establishment. At the present time the ships of the fleet had gone from Portsmouth to take part in the naval manœuvres; otherwise the members would have been much more strongly impressed by their presence with the enormous reserve of power which England now possessed in ships completed and ready for service at the shortest notice, and of which the fleet reserve in Portsmouth dockyard was only one illustration. In the three great naval ports of the country there existed a numerous and powerful reserve of the most modern ships, ready for service, in addition to the large fleet which was in permanent commission. While specimens might be seen of all or nearly all the classes of vessels building under the Naval Defence Act, there would at the present time be no specimen visible in the dockyard of the class of which the "Royal Sovereign" was the first completed ship. That vessel he was sure would have been an interesting sight if she had been in port; but Portsmouth dockyard had proceeded with such extreme rapidity in her construction that, at a time when according to all precedent she would have still been here and open to inspection, she was already at sea, flying the flag of the Admiral commanding the Channel Squadron.

The PRESIDENT considered that the members were greatly indebted to Mr. White for the trouble he had taken to compile this paper; and he was sure that its interest would extend much further than the body of Mechanical Engineers now assembled in Portsmouth.

It afforded a proof that, with the best possible appliances, and with what he might call a marvellous combination of talent and good will, it had taken nearly three years to build the latest ironclad. It appeared to him that wars were getting shorter, and that the time occupied in preparing warlike materials was getting longer. The consequence was that it had become indispensable for a nation which desired peace to have not only an abundant reserve of warlike stores, but also vast powers of producing them; and it must be content to pay for the security thus obtained. In Nelson's despatches, written during the year and three-quarters 1803-5 when he was watching Toulon in the hope that the French fleet would come out and fight, he mentioned that frigates were sent from time to time to look into the harbour and observe what was doing, and they reported that various war vessels were in process of building and repairing; and by the time the fleet did at last come out, the French had managed to build and equip some new ships, and to send out a force superior to his. That was a thing which could not be done now-a-days. In the first place, no blockade was going to last so long as nearly two years; and in the next, two years would not suffice to produce a single ironclad or a single powerful gun. The only time therefore for building ships and guns was during a time of peace: so that, if ever war should break out, Britain might have a reserve such as no other nation or combination of nations could bring against her. The present paper would enable the members to understand what they would see this afternoon under the guidance of the officers who had kindly undertaken to conduct them over the dockyard; and he was sure they would all desire to accord a hearty vote of thanks to Mr. White for the preparatory information which he had given them.

SHIPBUILDING IN PORTSMOUTH DOCKYARD.

Plate 26.

Fig 1.

"Centurion."

Mechanical Engineers 1892.

Scale $\frac{1}{600}^{th}$

Feet 10 0 50 100 150 200 250 300 Feet

Plate 26.

Fig. 2. *Plan of "Centurion".*

Fig. 3. *Plan of "Royal Arthur" and "Crescent".*

Mechanical Engineers 1892.

Feet 10 0 50 100 150 200 250 300 Feet

Scale $\frac{1}{600}^{th}$

SHIPBUILDING IN PORTSMOUTH DOCKYARD.

Plate 28.

Fig. 4.

"Royal Arthur" and "Crescent."

Mechanical Engineers 1892.

Scale $\frac{1}{600}^{th}$

Feet 10 0 50 100 150 200 250 300 Feet.

Plate 28.

Fig. 5. "Fox."

Fig. 6. Plan.

Mechanical Engineers 1892.

Feet 10 0 50

100

150

200

Scale $\frac{1}{600}^{th}$
250

300 Feet

Midship Sections.

Fig 7. "Centurion."

Fig 8. "Royal Arthur" and "Crescent."

Fig 9. "Fox."

Mechanical Engineers 1892.

Scale $\frac{1}{300}^{th}$

Feet 10 0 10 20 30 40 50 60 70 80 Feet

PORTSMOUTH.

Plate 31.

D Royal Dockyard, Portsmouth (See Plates 32 and 33)

V Royal Clarence Victualling Yard, Gosport (See Plate 64)

Scale 2 miles per inch.

PORTSMOUTH DOCKYARD.

Plate 32.

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Mechanical Engineers 1892.

Plate 32.

PORTSMOUTH DOCKYARD

Plate 33.

Plate 33.