the two. On the gantry is mounted a double cantilever crane, having an effective reach of 95 ft. on each side of the centre; this outreach is sufficient for a ship 70 ft. broad on each side of the trestle. The height of the cantilever above the ground is some 90 ft., the load that can be raised is 15 tons, and if necessary a bulkhead up to that weight can be lifted bodily into place. The speed of lift for this weight is 100 ft. per minute, and for lighter loads 700 ft. per minute. The speed of the trolley along the cantilever is 400 to 800 ft. per minute, and of the whole crane longitudinally is 400 to 700 ft. per minute. All movements are made by electric power. Similar gantries and arrangements are used in other American shipyards. The view shown in fig. 80 (Plate VIII.) represents one of these structures as fitted in Messrs Cramp’s shipyard in Philadelphia.

At the yard of Messrs C. S. Swan & Hunter, on the Tyne, similar structures have been erected since 1894; besides carrying cranes, these have standards and stiffening girders, from which ships under construction are shored for fairing. Roofs and sides are fitted to protect the ship, and the workmen engaged in building her, from the weather. The side supports are three in number, and serve for two berths ; they are formed of steel lattice-work, with standards mostly 20 ft. apart. The clear height of roof is 83 ft., and clear breadth of berths 68 ft. and 73 ft.; a roadway on the ground level is left free on each side of the berths inside the standards. Two revolving 3-ton electric cranes travel along paths suspended from each roof ; their jibs have sufficient radius to lift material from the roadways and deposit it at the centre of the ships building. The longitudinal speed of these cranes is 300 ft. per minute; speed of lift, 100 ft. per minute. A third berth is served by a travelling cantilever crane on top of the adjoining roof. At Messrs Harland & Wolff's yard at Belfast another modification was introduced in 1897 (see fig. 81, Plate VIII.). In this case the structure takes the form of a travelling gantry or bridge over the building berth, the legs running on rails at the ground level. The gantry, which is driven by hydraulic power, has three traversing cranes and four 4-ton swing cranes. It was designed to facilitate the lifting of plates and portions of the structure into position, and also to support the hydraulic riveting machines and other appliances for the carrying out of the work. The success of the appliances, first used in the “ Oceanic,” has led to a further extension for other ships in hand.

Course of Construction

The first steps taken on the receipt at the shipyard of the design drawings and specifications, which have been generally described on page 957, have for their object the provision of detailed drawings of the structural arrangements, which will enable materials for the various parts to be ordered from the manufacturers, and of information for the guidance of the workmen in erecting the structure.

A wooden model of half of the exterior surface of the ship, called the “ half-block ” model, is immediately prepared from the sheer drawing, generally to a scale of ¼ in. to the foot for a large ship and a somewhat larger scale for a small one, and on its surface are carefully drawn the main frames, the edges and butts of the outer bottom or shell-plating, together with the positions of decks, longitudinals and other features which influence the detailed arrangement of the framing and shell- plating, the particulars of which are fixed by the specification and the midship and other sections. The work on this model is carried out concurrently with the laying off of the ship, which will be described presently, so as to be complete by the time the latter is sufficiently far advanced to enable full-sized measure­ments of the breadth of the plates to be obtained. The lengths of the plates are then measured from the model and the breadths from the mould loft floor, a small surplus on the net measurements being allowed to provide for inaccuracies; and the whole of the outer bottom plating ordered from the manufacturers. The whole of the framing is also ordered, the lengths of the various parts being measured from the model.

A similar block model is made to the shape of the inner bottom, if one is to be provided, or of the top of the ballast tanks, as the case may be; and in a battle-ship a block model will be made of the protective deck if it should have much curvature or sloping sides. All details of plating, framing, beams, carlings, hatchways, &c., will be shown on these models, and the dimen- sions of all the parts will be carefully measured off and the material ordered of the manufacturers; the breadths of the plating being obtained as in the case of the outside bottom plating.

For flat or nearly flat surfaces such as flat keel plates, vertical keel, bulkbeads, decks, engine and boiler bearers, &c., the detailed arrangements of plating and frames are made on draw­ings, from which the dimensions are taken for ordering the material from the manufacturers; while the drawings themselves constitute working drawings which are issued for general guidance in building the ship.

Drawings of details of important structural castings or forgings, such as the stem, sternpost and shaft brackets, are also among the earliest taken in hand, but the patterns to which these parts are made, when they are large and complicated castings as in a warship, cannot generally be completed without information obtained from the mould loft floor.

Laying off is the name given to the process of drawing the lines of a ship to full size in plan and elevation in order to determine the exact dimensions of the most important and fundamental parts of the structure. The necessity for drawing to full size arises from the extreme accuracy with which the dimensions of the various parts must correspond with one another in order that when assembled there may be no irregularity or unfairness in the surface of the ship; the methods of ordinary mechanical drawing to a small scale being inadequate for this purpose, on account of the analytically indeterminate nature of the curves which define the form of the ship. The process is carried out on a specially planed and blackened floor, most conveniently of rectangular shape, and of such a size as to take in the full depth of the ship in its width. The building or room in which the floor is situated is called the “ mould loft,” and is an important adjunct to the shipyard drawing office.

The rationale of the methods of projection of points and lines and rabatment of planes used in laying off is subjected to a de­tailed examination in the article Geometry, part III., *Descriptive,* vol. xi., and therefore will not be referred to in this article, which is confined to a description of some of the detailed problems which occur in actual practice, the solutions being often approximations which are found sufficiently exact for practical purposes.

In different localities and in the construction of different types of vessel, the extent to which the process of laying off to full size is employed varies considerably. In some yards laying off on a large scale on paper is relied on almost entirely, and very little full-sized work on the floor is considered necessary. This chiefly applies to ships of stereotyped form, such as ordinary “ tramp” steamers, the lines of which have very little curvature for the greater part of their length. In the American Lake shipyards for the cargo vessels employed on the Great Lakes templates arc very carefully and ingeniously made for the framing, one set sufficing to mark off all the frames on the greater portion of the ship’s length. In a similar way one template is made for each strake of plating and used to mark off the whole of the plates of that strake, a slip mould being used when they begin to depart from the parallel midship body.

The types of vessels in which the greatest complication of structure occurs and in which the highest degree of accuracy in building is necessary are passenger ships and war vessels; the description of the process of laying off, which follows, while generally applicable to all types of vessels, refers more particularly to the practice followed in building war vessels at the British Government Dockyards and at the more important shipbuilding centres in the United Kingdom.

The nature of the Sheer Drawing, with a description of the prin­cipal lines shown on it, has been stated on p. 957. Specimen sheer drawings of different types of ships are shown on Plate IX. Fig. 83, Plate IX., is a sheer drawing of the Midland Railway steamer “ Londonderry,” designed by Professor J. H. Biles, LL.D., of length between perpendiculars 330 ft., breadth moulded 42 ft., depth 25 ft. 6 in., displace- ment 2200 tons, speed *21* ∙7 knots. Fig. 82, Plate IX., is the sheer drawing of the battleship “ Lord Nelson," whose dimensions and other particulars are set forth in the article on Ship, page 898. Her form over the midship portion below the water­line and above the turn of the bilge is flattened so as to enable her to be docked in a dock existing at Chatham when she was built, and at the same time to secure the greatest possible beam of ship at the water-line; and the bottom of the ship out to the dotted line in the half-breadth plan is absolutely flat so as to enable her to be docked on two or more lines of blocks whose upper surfaces lie in one plane, thereby reducing the docking strains, a system adopted for the first time in the "Lord Nelson ” and in all succeeding vessels of large size in the British Navy since this vessel. ln Plate IX. figs. 85 and 87, the half-breadth and body plans of the royal yacht “ Alexandra ” are given in association with the profile, fig. 84, in place of the usual outline sheer, which is omitted to save space. In each of these sheer drawings the names of the various lines have been added ; whereas in ordinary practice only the numbers of the stations in the sheer and half-breadth and of the sections in the body are given. In the sheer drawing, fig. 83, very little more is given in the three plans than the various sections and the traces of the planes, whose intersections with the surface of the ship they are; in such a case the sheer drawing is generally spoken of as *the lines,* and is only used for giving the outside form of the ship,