upperworks, and their power to resist a tensile strain. There is seldom a want of sufficient strength in the lower parts of the vessel to resist the crushing or compressing force to which it is subjected. The decks of vessels should not, therefore, be too much cut up by broad hatchways ; and care should be taken to preserve entire as many strokes of the deck as possible. The tensile strength of iron can be brought to bear most beneficially in this respect.

Though these are the strains to which a ship is most likely to be exposed, it by no means follows that there are no circumstances under which strains of the directly opposite tendency, when pitch­ing, or otherwise, may be brought by recoil to act upon the parts. The weights themselves in the centre of the ship may be so great that they may have a tendency to give a hollow curvature to the form, and it is therefore equally necessary to guard against this evil. When this occurs, the vessel is technically said to be “sagged,” in distinction to the contrary or opposite change of form by being hogged. The weight of machinery in a wooden steam-vessel, or the weight or undue setting up of the main-mast, will sometimes produce sagging. The introduction of additional keelsons tended to lessen this evil, by giving great additional strength to the bottom, enabling it to resist extension, to which, under such circumstances, it became liable ; and, as the strain upon the deck and upperworks becomes changed at the same time, they are then called upon to resist compression.

When the ship is on a wind, the lee-side is subjected to a series of shocks from the waves, the violence of which may be imagined from the effects they sometimes produce in destroying the bul­warks, tearing away the channels, &c. The lee-side is also sub­jected to an excess of hydrostatic pressure over that upon the weather side, resulting from the accumulation of the waves as they rise against the obstruction offered to their free passage. These forces tend in part to produce lateral curvature. When in this inclined position, the forces which tend to produce hogging when she is upright also contribute to produce this lateral curvature.

The strain from the tension of the rigging on the weather side when the ship is much inclined is so great as frequently to cause working in the topsides, and sometimes even to break the timbers on which the channels are placed. Additional strength ought therefore to be given to the sides of tho ship at this place ; and, in order to keep them apart, the beams ought to be increased in strength in comparison with the beams at other parts of the ship.

The foregoing are the principal disturbing forces to which the fabric of a ship is subjected ; and it must be borne in mind that some of these are in almost constant activity to destroy the con­nexion between the several parts. Whenever any motion or working is produced by their operation between two parts, which ought to be united in a fixed or firm manner, the evil will soon increase, because the disruption of the close connexion between these parts admits an increased momentum in their action on each other, and the destruction proceeds with an accelerated pro­gression. This is soon followed by the admission of damp, and the unavoidable accumulation of dirt, and these then generate fermentation and decay. To make a ship strong, therefore, is at the same time to make her durable, both in reference to the wear and tear of service and the decay of materials. It is evident from the foregoing remarks that the disturbing influences which cause “hogging” are in constant operation from the moment of launch­ing the snip. As this curvature can only take place by the com­pression of the materials composing the lower parts of the ship and the extension of those composing the upper parts, the importance of preparing these separate parts with an especial view to withstand the forces to which they are each to be subjected cannot be over­rated by the practical builder.

In his *Manual of Naval Architecture,* Mr W. H. White gives illus­trations of tho still-water strains upon two ar­moured ships in the British navy the “ Minotaur ” and the “Devas­tation.”

In these diagrams the curves B represent the distribution of the buoyancy. The ordinates of the curve are proportionate to the displacement of ad­

jacent transverse sections of the ships. The curves W represent the distribution of the weight of the ships and their lading.

The curves L repre­sent the excesses and defects of buoy­ancy obtained from the two curves B and W and set off from a new base line. The

excess of buoyancy above the line is exactly equal to the defect of buoyancy below it. The curves M indicate the bending moments. The ordinates of tho curve lying above the base are obtained by summing all the moments,

whether upwards or downwards,

about the point in the length of the ship where the ordinate is taken. It may happen, as in the case of the “ Devastation,” that the moments will tend to cause hogging for a portion of the length and will then change their character, and at other por­tions of the length will tend to cause sagging. Where the curve M crosses the base line there is no strain of either hogging or sagging tending to bend the ship there. In the ‘ ‘ Minotaur ” there is a hogging tendency throughout. The amount at the midship section is very great, being represented by the moment 4 *5* feet × 10·690 tons. After Sir Edward Reed left the Admiralty he strongly expressed his fears that this strain was too considerable for safety in the “Minotaur” and “ Agincourt.”

*Designing.*

The principal plans of a ship are the “ sheer ” plan, giving in outline the longitudinal elevation of the ship; the “ body” plan, giving the shape of the vertical transverse sections ; and the “half-breadth” plan, giving the projections of transverse longi­tudinal sections. In addition to these the builder is furnished by the designer with elevations, plans, and sections of the interior parts of the ship, and of the framing and plating or planking.

The thicknesses or weights of all the component parts are specified in a detailed specification, in order that the ship when completed may have the precise weight and position of centre of gravity con­templated by the designer. In the case of ships built for the British navy all the building materials are carefully weighed by an agent of the designer before they are put into place by the builder. As each section of the work is completed, the weight is compared with the designer’s estimate in the designing office. As soon as the incomplete hull is floated the actual displacement is measured, and compared with the weights recorded as having gone into the ship. It is also the practice in the Royal Navy to calculate the position of the centre of gravity of the incomplete hull, and its draught of water before it is floated, in order to avoid all risk of upsetting from deficiency in stability at that stage of construction. The ship is usually found to float in precise accordance with the estimate. When completed ships float at a deeper draught than was intended, or are found to be more or less stable than was wished, this is nearly always due to additions and alterations made after the com­pletion of the design. Where the designer is at liberty to complete the ship in accordance with the original intention there ought to be precise correspondence between the design and the ship.

In designing a ship of novel type the designer has to pass all the building details through his mind and assign them their just weights and proportions and positions. Every plate and angle bar and plank, every bar and rod and casting and forging, and every article of equipment has to be conceived in detail and its effect estimated.

*Building.*

The term “ laying off” is applied to the operation of transferring to the mould loft floor those designs and general proportions of a ship which have been drawn on paper, and from which all the preliminary calculations have been made and the form decided. The lines of the ship, and exact representations of many of the parts of which it is to be composed, are to be delineated there to their full size, or the actual or real dimensions, in order that moulds or skeleton outlines may be made from them for the

guidance of the workmen.

A ship is generally spoken of as divided into fore and after bodies, and these combined constitute the whole of the ship ; they are supposed to be separated by an imaginary athwartship section at the widest part of the ship, called the midship section or dead- flat. The midship body is a term applied to an indefinite length of the middle part of a ship longitudinally, including a portion of tho fore-body and of the after-body. It is not necessarily parallel or of the same form for its whole length.

Those portions of a wooden ship which are termed the square and cant bodies may be considered as subdivisions of the fore-bodies and after-bodies. There is a square fore-body and a square after­body towards the middle of the ship, and a cant fore-body and a cant after-body at the two ends. In the square body the sides of the frames are square to the line of the keel, and are athwartship