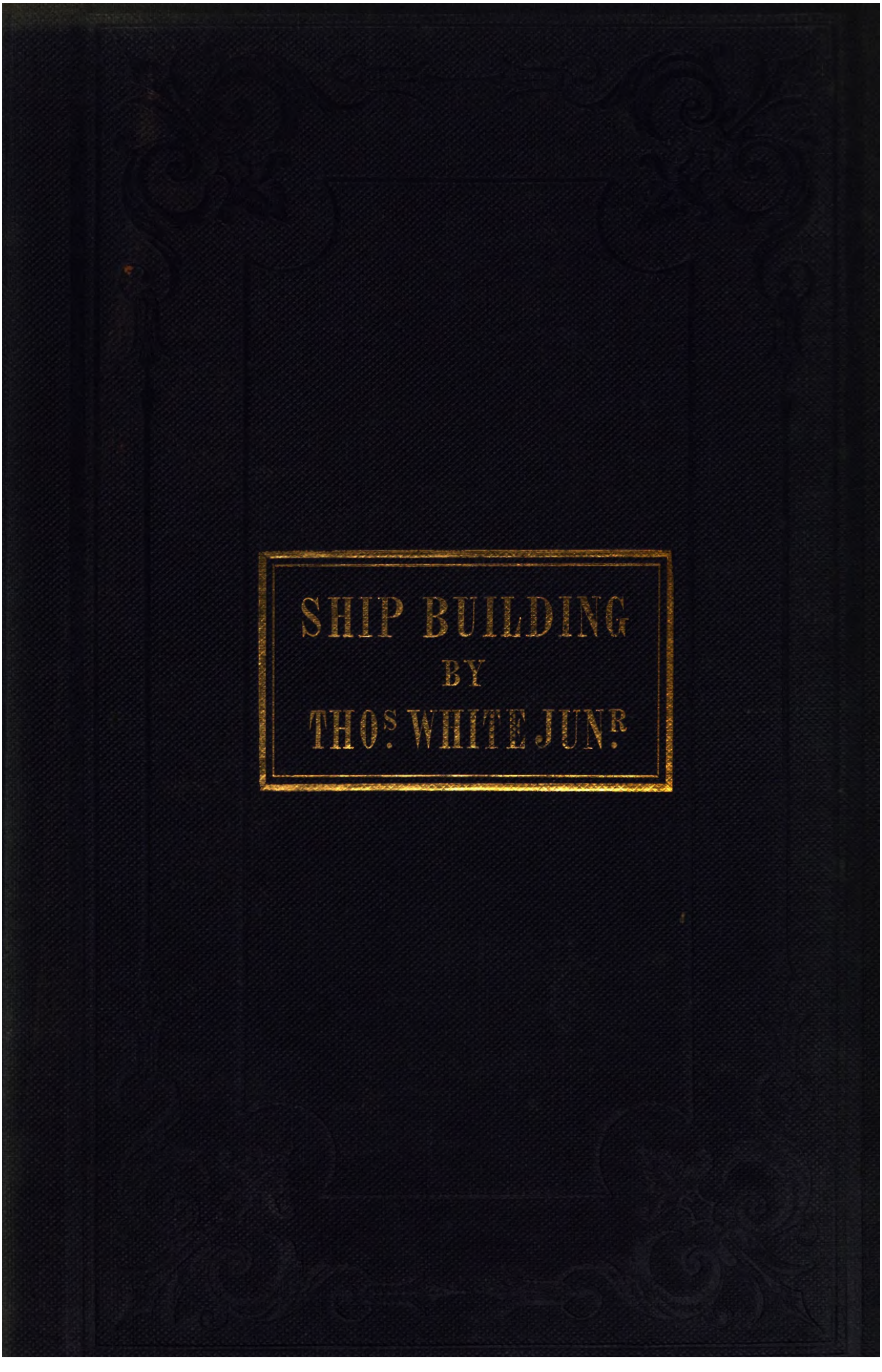

SHIP BUILDING

BY

THO^{S}. WHITE JUN^{R}.

THE

THEORY AND PRACTICE

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THE Author feels it requisite to explain that the following Work was sent to press in the autumn of last year, but was necessarily delayed by his absence in Spain. Some variations of expression would otherwise have occurred; but as they do not affect the general question, he did not consider them of sufficient importance to reprint any portion, or further to delay the publication.

PORTSMOUTH, *August*, 1847.

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INTRODUCTION.

THE inconvenience felt by the author in his youth, from the want of a familiar treatise on Naval Architecture; the great expense of the works then extant, such as Stalkart and Steele; and the desire to be useful in a profession which involves so many important and national interests; are the circumstances and motives that induce the publication of this concise treatise.

Since the period alluded to, several works, it is true, have been presented to the public. These, however, leave us without a succinct compendium, calculated to expose the defects of the old system, and to offer suggestions for the formation of bodies, according to the extended experience of the present day; and to afford, at the same time, sufficient directions for laying off in the Mould Loft. These points have never yet been comprised within a compass that is inviting and accessible to the mass of the profession, and to the many builders who are more or less excited to emulation by the rapid strides which this important science is now happily making, under the encouragement of an enlightened Admiralty, the advantage of a royal and wealthy Yacht Squadron, and the mighty impetus of railroad, steam, and other improved means of transit.

The treatise of Creuze is good, and well suited for the article " Ship Building," in the " Encyclopædia Britannica," for which it was expressly written; but as such it is of too general a character. That of Fincham on " laying off" is also invaluable; but it relates chiefly to the Mould Loft.

Since the publication of these, however, so much attention has been awakened to this important subject, so many efforts made to improve the qualities of the various classes of vessels, and the results of so many experimental squadrons presented to the Admiralty, that a few remarks upon the leading features of these alterations and improvements, and suggestions for assimilating, and thereby simplifying the bodies of the various classes of vessels designed for the same service, may not now seem out of place.

To throw, then, some additional light upon these subjects; to give some plain directions for actual building, which may be sufficient for practical men; in a word, to give just what is requisite for carrying on the reader to the larger and more scientific works on the subject; these are the objects which we propose in the present attempt.

The propriety of making public the improvements that are decided on, before we have availed ourselves of the benefit, has been much discussed; but if, as all admit, foreigners have had the advantage of us, hitherto, in model, and have paid more attention to the science itself, is it not (worse than mere contraction of spirit) folly, to suppose that they will not soon progress equally with ourselves from their own resources? On this point, the author's mind is so fully conveyed in the admirable sentiment of Mr. Creuze, that he has taken the liberty to quote it.

" It has been objected to works having for their object the diffusion of information on naval improvement, that we, as Englishmen, should be cautious in publishing such knowledge, but should rather endeavour secretly to avail ourselves of it; because an opposite course might tend to diminish the superiority of our navy, by increasing the efficiency of that of our rivals. We do not believe that this conclusion is at all correct, and we shall presently endeavour to establish the position which we thus assume. But, even were it absolutely and incontrovertibly correct, it could only be applied to the question of the improvement of Naval Architecture, by the advocates of a most selfish and narrow-minded policy. A broad line of distinction should be drawn between the means of preservation and the means of destruction. The means of preserving human life should be considered the common property of all mankind; the means of destroying it, unless the national safety should demand it, a secret neither to be divulged nor used.

" Every man who can, in any way, add to the security with which the sea may be navigated, is as much bound to diffuse such knowledge, as he would be to save a drowning man from the waters. Whether the additional security be obtained by the improvement of the chart, which is the guide to navigation; or of the chronometer and sextant, which render that guide available; or, finally, of the ship itself; the additional security is a boon to mankind, and the inventor or promulgator of the means by which it is attained is a benefactor to his species; because, in proportion as the means and aids of navigation are perfected, its dangers are diminished; and in proportion as the knowledge of the means for improving them is diffused, so is the whole family of man benefited, and the natural state of mankind, which may be presumed to be one of peace and good-will, ameliorated."

If the pretensions of the author be inquired for, he has only to observe, that in his family, four successive generations, for just one hundred years, have been practical and extensive ship-builders; that three of these generations are now in actual business, having been, for the last thirty years especially, engaged in building a greater *variety* of vessels than has been found in any other yard in the kingdom; and that the successful results of this experience are now testified by the Government, by the Royal Yacht Squadron, and the Board of Customs, besides the leading branches of the merchant service and steam navigation. Moreover, the principles here advanced are not the speculations of the present day, so fertile in projections, most of which are based more or less on the " certainty of the glorious uncertainty;" but are the result of the experience of successive generations, as shown by the midship sections in Plate V., from the drawings of the progenitor, bearing date, A.D. 1770. The author's claim, therefore, to appear thus before the public, will, he trusts, be fairly admitted.

NAVAL ARCHITECTURE.

CHAPTER I.

THE necessity for the science of Naval Architecture is universal, whether we consider the formation of the globe, with its natural divisions of land and water, or the established dependence of one part of the world upon another, for their mutual intercourse, for their necessary supplies, or their luxurious gratifications. This necessity, of course, increases in an insular situation; and where defence or war are to be provided for, is of paramount importance.

All these positions characterize Britain, "the land we live in;" and it is a question worthy of serious discussion, why necessity and experience have done so little towards maturing a science upon which so much depends.

The limits of this work will allow merely an outline of the leading causes.

The first source of defect and deficiency is the acknowledged difficulty of the subject. The astronomer has now ample data upon which to build his theories, and pursue his investigations. The civil architect has a base upon which to erect the most ponderous building; his projection is for a definite purpose, and the dangers to which it is exposed are fully known. But the naval architect can bring few such points to his aid; the great variety of purpose, of service, and of danger, to which the same vessel may be exposed, place him in a very difficult position.

The next cause of defect is, the fewness of the men of education who have been brought into contact with the subject as a science; and the culpable neglect on the part of the Government of those who have signalized themselves therein.

Mungo Murray was the most practical shipwright and most intelligent author on the subject in his day; but he lived a working man, and died in that grade, connected with one of the Government yards.

Stalkart, a private builder, was the finished draftsman of his time. The precision of his plans, and the adaptation of his work and style to the practical builder, have gained for him the respect of every candid mind; but his devotedness to his undertaking for the public good ruined him; and though his work was in the hands of every student of the art in every dockyard, and is the basis of much that has succeeded, yet he was never noticed or rewarded.

Another serious hindrance is the great expense of practical experiment, together with the becoming tenacity of Governments in expending large sums upon uncertain projects.

Experience has shown us, also, that theoretic demonstration, and maturity in practice, are fruits not often gathered in the same field. Our dockyards are the prolific source of the former; there many men of great ability and superior education are to be found; there "many hands make light work," and much time can be, and is, devoted to this object. But in these schools there exists a radical defect. Many have been the men, and many there now are, of great talent, who have never drawn an original line in their lives, with a view to build therefrom, but have gone on in the beaten track of rearing their fabrics from plans and orders sent from "aloft." We except, of course, the few engaged of late in the experimental ships. In these yards, the fairing of a body—the laying off—the most approved method, even if it be the most expensive, of putting work together,—these and many more real and great advantages are to be found; but all this may exist without once touching the principles of formation: with these the dockyard officer has very little to do. This department has been left with "the Board;" and if we examine *their* proceedings, for past generations, we shall find that little or no deviation has been allowed from the midship section and leading features of Chapman the Swede, since they first adopted them, until the experimental ships were designed, except the occasional taking off and building from, the ships of acknowledged superiority taken in the war. Indeed, it would almost appear—owing, perhaps, to the great uncertainty in fundamental principles, in the laws of fluids, and the combined influence of wind and water, and to the fact that students in this art seldom finish their education at sea, as they ought to do—that the heads of departments have been content with the naval success of their day; that the men of science employed in the administration have not been disposed to risk their reputation and salary by uncertain experiment; and that all have thus adopted the well-known maxim of Nelson, "Let well enough alone."

On the other hand, in merchant yards, no such restrictions have fettered the talent and impeded the enterprise of the scientific and practical builder. The Royal Yacht Squadron has given a mighty impetus to talent; and to the unrestricted character, and the multiplicity of vessels which this field has presented, we may attribute the great advance of marine architecture in our day; while its reaction on the navy is becoming apparent.

The Honourable Board of Customs has done much in the same way. They sought out the ports and builders highest in repute, about twenty years ago, ordered twelve cutters, and then proceeded to patronize the most successful competitors. In this way they have gone on, gathering and securing improvements, until the fact has been palpable, that the Government-built cutters have been lost in the distance; which is confirmed by the orders given of late, for the leading craft to be docked and taken off.

The liberal and just encouragement thus afforded by the Honourable Board of Customs, has been checked and withdrawn, by the Treasury giving leave to the present surveyor of the navy to issue his own drafts exclusively. Various have been the trials, and the sequel is to be deplored.

And, last, but not least, strange as it may seem, legislative enactments have ever been the bane of this important science. If a vessel needs a nominal character for tonnage, the system of admeasurement for ages was such (and it is but little improved) that numbers of ships were built to carry double the amount in dead weight of their register tonnage. The manning of them, with all dues and charges, was made upon this false character; indeed everything, as by law established, has been well calculated to call forth the cupidity of the human mind; and it need scarcely be remarked, that where this is the case, everything else is in danger of being sacrificed.

It may be asked, how these remarks can apply to the Royal Navy, since no such motives can there be in operation. It is not more strange than true, that there has been the same niggardliness in reference to nominal tonnage for men-of-war, as though they, too, had to evade, as far as possible, the heavy dues and charges entailed on the merchant trader; and this in despite of the fact, that two or three hundred tons in the admeasurement of a man-of-war, are added without any expense worth naming; as the length and depth are not altered, only a little additional breadth being required, and that mainly at the load water-line amidships. Yet so it has been, and little wonder will be experienced, that, in the face of so many difficulties, we have made such limited progress towards maturity in our natural and national defences, and in the improvement of our mercantile marine, so extensively relied on for the resources of the Exchequer, and the advancement of which is so essential to the safety and comfort of human life.

It must be admitted, that many more truly scientific men have given their attention and assistance to this subject abroad than we have found at home; and the earlier treatises being in languages with which we were unacquainted, particularly the Swedish, in which Admiral Chapman wrote, the Continental architects had great advantage over us, during the long wars, &c.

The past should suffice, indeed it must suffice; for one thing is certain, that in sailing models, other nations have ever had the pre-eminence; as may be gathered, not only from fact, but from the testimony of all those who have written on the subject, and whose integrity in their statements and warnings has been superior to their professional and national predilections.

Feeling, then, that we must no longer depend upon military prowess alone, but on keeping pace with the rapid advances making by other nations, on all the points bearing upon this great science, we trust that this attempt may contribute its mite towards the desideratum. The day is now happily come, when our enlightened Admiralty seem determined to make an open question of it, and to gather the experience of the nation, come whence it may, on points of national importance.

CHAPTER II.

HAVING glanced at the defects of our system, we would offer some remarks on the different qualities necessary in combination to form bodies suitable to the various services in which a ship is engaged.

The first general principle, and which will apply to all classes of vessels, is STABILITY; for, as all construction has reference to bodies in a vertical position, it is evident that every degree of inclination is calculated to affect, and, if carried far, to outrage many of the principles advocated by the architect; besides which, the safety and comfort of the crew are connected with it.

We would here pause to offer a tribute to the present surveyor of the navy, Sir William Symonds, for having delivered our "wooden walls" from the trammels of ages; from a defect that has always been known and complained of, and which, in different circumstances from those we have been placed in, with regard to our enemies, might subject us to serious disadvantage. He has greatly extended the beam of his vessels; he has disregarded the bug-bear of nominal tonnage; and he has based his alterations on a principle sufficiently tried, in a class of vessels always built with a greater proportion of beam, although using about the same momentum of canvass; viz., the cutters, which are the fastest and most weatherly class afloat. True, this is only the extension of a known and tried principle; so we may say of Columbus' egg: but the wisdom of the surveyor's predecessors fell short of this improvement, although they were aware of its importance, as was manifest when they endeavoured to remedy the want of stability in the navy, by doubling the ships with solid balk, extending the beam amidships some two or three feet; notwithstanding which, they continued to build on the old and contracted dimensions.

Breadth of beam, however, though unquestionably the basis of lateral stability, is by no means all that is required. It may even prove a source of danger, and increased wear and tear; for, when unaccompanied by due proportions in other respects, and when all the power is sought for at the load water-line, the vessel will immediately fall to this bearing, and, the reaction being as sudden, the rolling will be incessant and severe, the stress upon the rigging very great, and the masts, in consequence, endangered. Here, we consider, is to be found the great defect in the surveyor's midship section; it is comparatively straight from the keel to the water-line; and, as such, is manifestly deficient in bearing, until its extreme immersion takes place, which is sudden almost to a jerk; whereas a rounder line would prevent the great degree of lateral inclination, and what must take place would be much more easy. The advantage of this, in comfort upon the deck, efficiency at the guns, wear and tear of the rigging, and, indeed, the safety and comfort of the whole, must be apparent.

As capacity, stability, and general adaptation, are primarily dependent on the form of the midship section, the author would here present a leading feature of his design.

The dead-flat of vessels has assumed a great variety of forms; but they have all been irregular figures, rendering it impossible to attain a scientific formation; since, before they can be adopted by any builder, reference must be had to some previous draft; to say nothing of their acknowledged errors. It is, therefore, obviously necessary and important to have a regular mathematical figure, *deduced from the dimensions* determined on, which can be formed independent of any such reference or extraneous aid, and which shall, at the same time, combine all the necessary qualities. This, it is pretty fully proved, may be obtained by a perfect semi-parabola from the water-line to the keel, the formation of which will be fully described in its proper place.

Rake of stem, to the extent that has hitherto obtained, is a palpable absurdity. It was extreme in the old school; and our ten-gun brigs, proverbially called "coffins" in the navy, had the stem at an obliquity with the keel of about thirty degrees; by which, of course, just so much body and sustaining power at the point of greatest efficiency, from its immersion, was lost. Every thing was tried to obviate this: the foremast shortened, so that one seemed almost to be able to touch the foretop from the forecastle; yet they pitched as before, numbers foundering during the war, and several having done the same since that period.

It will scarcely be believed that many of the ships of the present surveyor have nearly the same rake; and to counterbalance this, and support the fore body, an extreme fulness of harpin is necessarily adopted by him. The inevitable result of such a formation is, that, having no bearings below, in a pitching motion the vessel is suddenly immersed, and as suddenly brought up again, by the extreme fulness aloft. That this is a defect will more clearly appear by reference to Plate I., fig. 1, which is a drawing of the fore body of H.M. ten-gun brig " Pantaloon," with which the surveyor made his *debût* as a naval architect. The rake of stem is precisely that of the old ten-gun brigs, and the loss of displacement, as compared with the more upright stem ticked in, fig. 2, is nearly ten tons. This amount of sustaining power would prevent a pitching motion most materially; and if so, the propelling force which, with the old bow, is expended in pitching, would, with the other, assist in sending the vessel a-head. Nor is this all; the elongation of the bow below gives a water-line which experience, amounting to demonstration, has shown to be the proper form for the easier division of the fluid, occasioning, at the same time, less broken water to inundate the decks. This is the more important, as a very little experience at sea shows indisputably, that it is the sea, which is broken by contact, that produces inconvenience and disaster, and that a sea otherwise broken is only to be met with in extreme cases.

Several ships of this form, designed by the surveyor, have been dismasted at their anchors—one in the Mediterranean, and another at Spithead; while all the merchantmen and colliers, in the latter case, rode in safety.

A raking stern post is even less defensible than a raking stem, as the latter, in moderation, may indeed assist in keeping the anchor clear of the fore-foot; while the more upright the stern post is, the better the vessel will steer.

The placing of these extremities more upright, or even perpendicular, is not in the least at variance with one of the results most clearly arrived at in the series of experiments at Greenland Dock,* viz., that made with the parallelopipedon (a twelve feet three inch deal), in which, after the resistance of that figure, with square ends and of various lengths, was determined, they gave to it a circular wedge end (like a box-iron), Plate III., fig. 5;

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* These experiments were conducted by the indefatigable and philanthropic Colonel Beaufoy, while at the head of a "Society for improving Naval Architecture," which held its first meeting at the "Crown and Anchor," in 1795, but which was not afterwards supported. This society laid the foundation of much good; but its elementary proceedings were necessarily tedious and expensive, and, being without patronage, the results are now where the projectors left them. Happily these are preserved by the munificent and praiseworthy efforts of Henry Beaufoy, Esq.

and also one with an inclined plane (like a London barge); and it is remarkable, that although the water impinges at the same angle in both cases, yet the latter form offers considerably less resistance. Hence the conductors concluded that vessels should be built with inclined planes at both ends. The upright stem and post do not defeat this; for, immediately upon leaving these central points, the buttock lines aft, and vertical lines forward, show precisely a series of inclines; while the upright centres give an opportunity of elongating the water-lines; and the perpendicular stern post gives much easier steerage.

In the general idea of a "clean run," much error has been "run" into. If we refer to Plate I., fig. 3, we shall find, in the "Pantaloon," an extremely fine run, and the quarters flanging off almost at right angles. This, of course, causes an excessive curvature of the timbers, which involves a corresponding compound curvature of the water-lines, both of which should, as far as possible, be avoided; for (to say nothing of the conversion of timber), while we know little of the actual operation of fluids upon a body in motion, yet we are sure that they will flow more easily and quickly in right lines than otherwise. A running stream is greatly impeded by windings; and this principle, as applied to the point in question, was fully proved by many of the experiments in Greenland Dock, before referred to.

For the better illustration of these remarks, it may be well to imagine the vessel just named sailing or riding in bad weather. In meeting the sea, from her great rake of stem, and consequent loss of bearing below, she immerses the whole area of the bow, which, being very full, throws her down abaft with violence, until the flat quarters cause a sudden stoppage, and thus action and re-action are equal, sudden, and severe.

Let us not be deemed personal, or invidious, in these remarks: the defects alleged characterize all the surveyor's vessels afloat, and many more whose frames are cut out; and there existed, not long since, a great probability of the British navy being remodelled on this doubtful principle; it therefore becomes a matter of national importance. If these remarks be incorrect, they will be powerless; if true, they relate to an evil that is incalculable in the results to which an inefficient navy might lead. We could wish, amid the multitude of returns moved for in the House of Commons, that copies of the official reports, from commanders of the experimental squadrons, with those from the frigates "Vernon," "Pique," &c., should be required; inasmuch as these experiments were mainly made to test the properties of this new class of vessels. We are aware how difficult it is to obtain disinterested reports, while parties to whom they primarily relate are in power; but, knowing most of the gallant men alluded to, we have every confidence in them; and if such reports were before the profession, it would be easy to demonstrate the remarks we have made, or as easy to refute them.

We would here observe that, after a most careful analysis of the various writers, at home and abroad (the best compendium of whose names and nostrums may be found in the Encyclopædia Britannica, seventh edition, article " Ship-building," or that article published separately by its author, A. F .B. Creuze, Esq.), we can derive from them no satisfactory conclusion about the data on which to construct a ship, so as to give " the why and the wherefore" to a demonstration. It would be worse than affectation to attempt it here: for while the able author just named has deplored the want of superior education in many practical men who might have further benefited the science, yet we cannot shut our eyes to the fact, that the school in which he was trained, which existed for above twenty years under the most favourable circumstances, sustained by Government resources, and which has had more than half that time since to exhibit its fruits, has done but little to advance the science, so far as positive qualities go, in the ships they have built, or even to illustrate the theory of their construction. We therefore look onward for this desirable consummation; not doubting that the bringing so many more mathematical minds into the field will be of great avail, when science shall have developed the laws of fluids, and told us how the water really moves under and about a ship in motion. At present, instead of professing to build ships upon any established or known theory, we avow our intention to be, that of deducing a draft from the form of vessels of decidedly superior character: and in this way to supply the want of sufficient data upon which construction should proceed. We need not wait until the curve of the solid of least resistance has been ascertained: but, by experiment, proceed with that form of body which is found most to unite the several requisite qualities.

CHAPTER III.

THE complete draft, Plate VI., is intended to exhibit two important projects; viz., *sailing on an even keel*, and building *all vessels designed for the same service from the same draft*, by the mere application of different scales.

With reference to the first of these, the difference of draft of water which has hitherto obtained, is an absurdity that can plead nothing but custom: and which has been handed down as the fruit of another error in placing the midship section too far forward, and following Chapman's gratuitous idea of a "full bow and clean run;" or, as it is termed upon our coast, a "cod's head and mackerel's tail."

We have verified our position in various ways: and it would be easy to institute comparisons, or to explode the objection advanced in print, that, to attain an even keel, would cause the immersion of the fulness of the after body, so as to create "dead water;" whereas, if we take a vessel with great difference in her draft of water, it will immediately appear, that all that is necessary to reduce it is, to cut up a portion of what is emphatically termed "dead-wood" abaft, which would not affect the general displacement. We have known a practical experiment, in a yacht of sixty tons, built with what is termed a "hollow bottom," which, occasioning large chocks in the seats of the floors, allowed the keel to be raised up abaft just one-fourth of the original draft of water, or two feet nine inches, and the bottom to be terminated at the rabbet, by what is termed a "straight floor." This vessel belonged to a cutter sailor of forty years' experience, who ran her in a trade where he constantly had opportunities of trying her with many of her own class, both laden and otherwise, before and after the alteration; and a whole season's observation showed no difference whatever in her sailing; but she was "lighter in hand"—that is, steered easier, from the reduced immersion of the rudder. We assert, then, the possibility, and great advantage, of reducing the whole draft of water by this means: allowing so much difference only as shall bring the water to the pumps.

Our next suggestion is of far greater importance, viz., the *building of all vessels, intended for the same service, from the same draft.* It is singular, that although the duty to be performed is the same, and the same qualities in constant requisition, yet, hitherto, every vessel that varies in tonnage has a different construction. We believe this to be purely accidental: certain it is, that our principle has never been tried to any extent, although we have sufficient demonstration before us in its favour. We find that the exact midship section of the "Harriet" cutter yacht, of 120 tons, built some twenty years since for the Marquis Donegal, then Lord Belfast, was extended and adopted in the "Water-witch" brig, of 330 tons; and the same has been carried out in the "Daring," of 450 tons, or sufficiently so for the illustration of this point, exact agreement not having been contemplated.

While, then, we have practical demonstration in proceeding upwards with this principle, we may adduce in its support, on the other hand, the extent to which the Government have *razeed* the large ships, proving that a good seventy-four makes as good a frigate, and a frigate as good a corvette; as instanced in the "Vindictive," "Warspite," "Magicienne," &c.

If comparisons be instituted, there will be found a much greater similarity than is generally supposed. Taking the stations of the several classes of ships at proportionate distances from the stern post, we shall find so little difference, that an observant architect naturally asks, Why any at all? so far, at least, as relates to the immersed body; seeing that entire similarity would be of an immense advantage, in simplifying the whole system. On the other hand, several models, exhibited at the Royal Polytechnic Institution, in illustration of this work, of the various classes from one draft, appear so dissimilar, from the superstructure above the load water-line, that a casual observer, even though a naval architect, would not realize their identity.

CHAPTER IV.

CONSTRUCTION OF THE SHIP, AND LAYING OFF IN THE MOULD LOFT.

In designing a ship, the architect will find an almost bewildering discrepancy in the proportions of the several dimensions to be found in the published tables of the navy, or the variations of different experimentalists, and still more so in merchant ships. This discrepancy may be accounted for, in the first case, by the fact that no attempt has been made to reduce these important data to anything like a system; while in the latter, it has arisen from the cupidity of owners, stimulated as it has been, by the injurious operation of the tonnage laws.

If a medium be taken between the extremes of the old school and the greatly extended breadth adopted of late, it will be found that a proportion of two-sevenths of the length, for the breadth, is suitable for general purposes. Some of the finest men-of-war, and many of the best merchant ships in the East India, South Sea, and Mauritius trades, are of this proportion, confirming, in the author's mind, the probability of its universal adoption.

The depth may be from five-ninths to two-thirds of the breadth, from which dimension it should be deduced, rather than from the length, as being the measure of stability.

A prevalent error in merchant building has been, the seeking great capacity in the fulness of the body, rather than by increasing the depth, and retaining the sharper form, best adapted for speed. In the latter case we obtain capacity, when required, and increased speed, whether loaded or light. Exceptions to this rule must be made in vessels intended to take the ground frequently, or requiring a small draft of water.

Having determined these principal dimensions, we may now commence the draft, which consists of three principal plans, termed the Sheer, the Body, and the Half Breadth, from either two of which the third may be deduced.

Begin with the profile, or Sheer Plan, which exhibits the broadside view of the ship, and in which the lengths and heights of all lines are projected. Erect the perpendiculars for the length, at each end of the vessel, upon a base which will represent the upper edge of the keel; the foremost at the fore part of the main stem, under the bowsprit, and the other at the after part of the stern post below. Formerly these terminations were the "points of admeasurement" for tonnage, according to law; and this should have been the only rule, but in the navy another method has always been adopted, and "builder's measurement," on the river Thames, differs from both. The new method, as by law now established, is indefinite, and liable to evasion; we shall, therefore, construct the ship, after which she may be "admeasured" as circumstances require.

Next set up the height amidships, upon a vertical section called dead-flat. This we recommend to be in the centre of the length; for although it has hitherto been placed nominally farther forward, yet as vessels have usually been made to draw more water aft than forward, the section of greatest area has in effect been carried considerably abaft the nominal dead-flat. This position of the midship section will assist in the attainment of an "even keel."

To ascertain the height of the sheer line amidships, add together the depth inside that may be determined, say 10 feet 4 inches (as in Plate II., fig 2); the floor, 11 inches; the thickness of the limber strake, 3 inches; and of the water way, 4 inches; these together will be 11 feet 10 inches; from which deduct the round of beam, 6 inches, leaving 11 feet 4 inches as the height to be represented in the Sheer Plan.

Add to this height the sheer determined on, which, in men-of-war, is from one-sixteenth to one-eighth of an inch to every foot in length; in merchant ships one-fourth, in cutters somewhat more, but all yielding to fashion or caprice. As a principle, the sheer is of importance, forming an inverted arch, to support the extremities of the vessel, which, from having reduced bearings in the water, invariably drop immediately after launching.

This curvature always increases, and is termed hogging.

Add the sheer to the depth upon dead-flat, and set it up upon the foremost and aftermost perpendiculars; the sheer line, passing through these three spots, should be the segment of a circle. This curve is not necessarily equidistant from the base at the ends, but varies, as the vessel swims upon an " even keel" or otherwise.

From the sheer line, lay off the rail, and the wale line, which are usually parallel to it, but not necessarily so.

The stem may now be drawn in, the fore edge of which is at the perpendicular aloft, and should correspond with it, but may be rounded below, to keep the anchor clear of the fore foot. The after rabbet, at the moulding determined on, breaks in fair with the base, or upper edge of keel. Proceed in the same way with the stern post, the after part of which should, in like manner, correspond with the aftermost perpendicular, and its moulded breadth below may be twice that of the upper end. The fore rabbet, which may be at the fore edge, with the base, and after rabbet of stem, form an entire line; which, for the convenience of future reference, we may term the line of formation; at which the whole body would end, were it not for the provision necessary to be made for the outside plank, causing this line to merge into what is termed the " bearding line," hereafter described, and shown in Plate III., fig. 2. The outer rabbet may now be got in, which is parallel to the line of formation, and distant from it the thickness of plank.

The rabbet at the wale, wing transom, and dead-flat on the keel, is a right angled isosceles triangle, whose perpendicular, or depth of the rabbet, is consequently half its base, or the breadth thereof (Plate III., fig. 4), and not an equilateral triangle, as generally directed; for it is impossible to obtain a sound caulking seam from such a form and edge.

There remains another line to complete this part of the draft, termed the inner rabbet, which represents mainly the inner edge of the plank, or more definitely the boundary of the caulking of the keel seam and wood ends. This, for sound work, is placed as nearly as possible at right angles with the varying form of the body. The inner rabbet aloft, and amidships upon the keel, is the vertex of the triangle; but on approaching the lower parts of the stem and stern post, where the plank is nearly vertical, it will necessarily be closer to the outer rabbet, in order to obtain a sound edge for caulking, which prevents the plank from being forced off. (See Plate IV., fig. 2, for the stern post, or Plate III., fig. 2, for the stem.) Great accuracy in these rabbet lines is necessary, as the endings of most of the longitudinal planes are taken from them.

Proceed by setting off the stations in the sheer plan, which represent the distances of the joints of the frames, a frame being two timbers. These distances are called room and space, and may be all equal, except that before dead-flat, which is greater than the rest, to admit a single timber to "break joint," as the bodies here separate, and reverse their moulding edges, for the convenience of having all timbers of the same denomination to bevel the same way. This would bring two heels and heads together, which is prevented by the single timber properly shifted. Such distance may be a space and half, the middle of the single timber being in the centre thereof.

The room and space is determined by Lloyd's scale for merchant ships; but this is far too general, making no distinction between a sharp vessel, that can scarcely carry her register tonnage, and one of the greatest capacity.

The midship stern timber, and thwartship view of the side counter timber, forming the lower and second counter, and stern, terminating the sheer and half breadth plans abaft, may now be drawn in.

Proceed with the Body Plan, which represents the various transverse sections of the ship. Draw in the middle line, perpendicular to a base, and the side line parallel thereto at the extreme moulded half breadth, also the half siding of the stem and stern post.

The midship section or dead-flat must follow, the form of which, for men-of-war and fast-sailing merchantmen, may, as recommended in another part of this work, be a perfect semi-parabola, below the load water-line; to describe which proceed as follows:—Draw in a level *aa* across the body plan (Plate II., fig. 2), producing it both ways, at the load water-line, which (for this purpose only) may be taken at three-eighths of the main moulded breadth, set up from the base. Bisect the middle line between the base and load line, as in B; strike a line from this point to *a*, the load water spot on the side line. Then, from the point B on the middle line, erect B *d*, perpendicular to the line B *a*, cutting *a a* produced in *d;* make *a e* and *a f* on the load water-line, on each side of the side line, equal to *a d*. Strike in several lines *e g*, *g g*, &c., parallel to the middle and side lines, which will afterwards serve for buttock lines; one of these may pass through *e*. Now, from the intersections of these, and of the middle line with the load line, take the several distances to the point *f*, and with these as radii, from the point *e*, as a centre, describe arcs, cutting the respective perpendiculars in *h h*, &c., as crossed; a curve through these spots will be the required parabolic section, between the load water-line at the side and the middle line. It will be necessary to cut off the point of this parabola for seating on the keel; the base of the body plan must now, therefore, be raised to the height of its intersection with the side line.

The area of this figure is easily ascertained in the calculation for displacement, being two-thirds of the base multiplied by the height. The displacement of the load water-line at this height, should be equal in the fore and after bodies.

The main breadth should be continued for some distance above the load water-line, so that when the ship inclines, no sustaining power may be lost. Above this, the upper works usually incline towards the middle line, or as it is termed "tumble home." This inclination varies considerably according to the taste of the builder, but is usually in a three decked ship about six feet; in a first class frigate, two feet six inches; in a merchant ship of 500 tons, one foot three inches. The advantages of "tumble home" are, relieving the side of the ship from the heavy appearance which a perpendicular form would give, termed a "wall side;" the protection of the upper parts, which are the most fragile and exposed, from contact; keeping the rail clear of the rigging, and bringing the guns nearer the centre of the ship, as they are raised above the centre of gravity.

Next, proceed to lay off the Half Breadth Plan of the ship, which represents her as cut longitudinally, in sections at right angles with the middle line. The form of the half breadth, for men-of-war, is best determined by a level line at the height of the lower port sills amidships, which, for the fore body, we recommend to be a semi-parabola, from dead-flat to the stem, whose distance between the points of construction shall be equal to the main breadth, as shown from the side line in the body plan (Plate II., fig. 3), to the middle line, and thence to E on the base, for the focus. Erect a number of perpendiculars, G, G, &c. (which may be so placed as afterwards to serve for the stations in the half breadth plan); take the distances from these perpendiculars to the point F, which, in the plate, is placed at the middle line of the body, and describe arcs from the focus

E cutting the corresponding perpendiculars; a curve through these intersections will give the form of the side, at the height of the midship port sill. For a middle line, set off the half breadth from the parabola, at the distance of dead-flat from the stem. Transfer the line just obtained to its proper place in the body plan. It must be observed, that in designing the several parts of a ship from complete mathematical figures, no allowance, of course, can be made for the arbitrary variations of "tumble home," &c.; this line is, therefore, drawn to the extreme moulded half breadth; but, as in most bodies, the midship section, at this height, begins to "tumble home," such variation must be drawn in, as ticked. (Plate II., fig. 3.)

As this line would make no allowance for the thickness of stem, the inner rabbet must be squared down from the sheer plan to the corresponding line in the half breadth, and the vertex carried as far before the intersection as may be necessary.

Transfer the breadths of this level line, on the several stations, to a corresponding level in the body plan; and, for the formation of the bow, make use of the fore end of the parabolic half breadth, just drawn in, as an entire section at one-fourth of the distance from the stem to dead-flat, the fore end meeting the keel. The same provision must be made for seating upon the keel, as was shown in the half breadth, to allow for the half siding of stem.

From the fixed points thus obtained, namely, the midship section, and parabolic timber at one-fourth of the length from stem to dead-flat, and the spots from the parabolic half breadth just got in, proceed to sketch in all the remaining timbers. To end them, where they come upon the keel, set off the rabbet upon the half siding, below the base, as *a b*, and from the lower edge describe an arc (as in Plate III., fig. 4), whose radius is the rabbet, or thickness of plank, and bring all the timbers in fair to the back of this arc, as *a c*. It will be found that, in this method of ending, the dead-flat, in sharp vessels, will rise above the base at the side line, as *a d*, occasioning a bearding, *f g*, which must be attended to, in cutting out the rabbet of the keel. If, however, it should be preferred to make this seating amidships the whole breadth of the keel, then a somewhat different arrangement must be adopted in ending the timbers, and the outer rabbet must be carried down the thickness of plank, and one-tenth more, as *a e*, forming the rabbet, *a g e*, otherwise the plank will not bury itself, as will be seen by striking it in at the back of the floor; and for the respective endings, reference must be made to the inner rabbet, as struck in in the sheer plan, for the height, and in the half breadth for the distance in from the half siding.

These inner rabbet lines are drawn in the sheer plan, from the centre of the rabbet amidships to the lower part, forward and aft, upon the keel; and in the half breadth, from the depth of the rabbet amidships, to the thickness of the plank at both ends of the vessel.

Transfer the heights of the several stations in the sheer plan, to the corresponding timbers in the body. Transfer the several breadths at these intersections, to the stations in the half breadth plan, a curve through these spots is the top half breadth. To end this and all other sheer or level lines, square down the intersection of the sheer with the outer rabbet on the stem, to the corresponding line in the half breadth plan; describe an arc from this point, whose radius is the breadth of rabbet, and bring the line in fair with the back of it, terminating it at the intersection with the inner or middle rabbet, squared down from the stem or post to its corresponding line in the half breadth plan.

The body being thus formed, proceed to prove or fair it.

First by WATER OR LEVEL LINES, parallel to the base, which are shown by the surface of the fluid, at different degrees of immersion. The form of these lines must be a prominent consideration in designing a draft, whereas the other lines deduced from the body are used only for proof, and their respective forms engage but little attention.

These lines are obtained from levels, parallel to the base in the body plan, taking the distance from the middle line to the intersections with the several timbers, and setting them off upon the corresponding lines in the half breadth plan; the ending must be obtained as directed for the top half breadth.

As vessels seldom swim upon "even keel," their actual water-lines must be obtained by striking in the draft of water from stem to stern, in the sheer plan, and carrying the heights of this line upon the several stations, to the corresponding timbers in the body plan. Then take the breadths at these intersections square from the middle line, and transfer them to the half breadth plan; pass a curve through these spots, and end it as the level lines just described.

Proceed, secondly, to fair the body by

DIAGONALS.

These lines differ from the levels, as they intersect the body in a direction oblique to the middle line. (See Plate III., fig 1.) They are laid off by taking the distances from the middle line in the body, in the direction of the diagonal, and setting them off in the half breadth upon the corresponding stations. For the ending, take the height in the body plan, where the diagonal intersects the inner rabbet, as in Plate III., fig. 1 ; transfer this height to the inner rabbet on the stem in the sheer plan, and square this down to the middle line in the half breadth plan, as *b d;* take the distance from the middle line in the body plan in the direction of the diagonal, to the inner rabbet, *a*, and set this off from the middle line in the half breadth plan, upon the squaring down, as crossed. This is the ending of the diagonal in all bodies whose main half breadth is within an angle of forty-five degrees with the middle line; but if the vessel be of a fuller description, it must be terminated by taking the height in the body where the diagonal intersects the half siding of the stem, and transferring these heights to the after rabbet in the sheer plan. Square this down to the middle line of the half breadth; then take the distance in the body plan from the middle line in the direction of the diagonal, to the half siding, and set it off in the half breadth plan, upon the line just square down. Should the form of the body render it doubtful which ending must be taken, set them both off, and use that which brings the line far thestin.

These directions will apply to the after body lines that end upon the stern post; but where they cross the wing transom, proceed as follows:—Represent the wing transom in the three plans, as Plate IV., figs. 1, 2, and 3, with the margin, which is a line at the after part of it, parallel to the upper edge, and distant from it the thickness of the tuck rail, or about that of the bottom plank. The transom usually has a round forward and a round down, about equal to the depth of the margin; the former to give a more airy appearance to the tuck rail, and the latter to reduce the abrupt finishing of the sides of the ship with the stern. The height of the transom and margin must be shown in the sheer plan, and squared down to the half breadth, where the round forward is represented; and also transferred to the body plan, where the round down is shown. The diagonals which cross the transom must be ended by taking the distance square from the middle line in the body plan to their intersection with the margin, and setting this distance off upon the corresponding margin in the half breadth plan.

If the vessel has a round, or elliptic stern, or the bottom plank worked up to the counter, the several diagonals must be ended as shown in Plate II., fig. 4, where the lower diagonal, marked No. 1, ending upon the stern post, is treated exactly as directed for the fore body; the second is ended on the stern, by transferring its height on the middle line of the body, as *a*, fig. 2, to the counter timber in the sheer plan, and squaring it down to the middle line in the half breadth, as *a*. The third or upper diagonal, ending upon the knuckle, is treated in the same manner as those that cross the wing transom.

BUTTOCK LINES

When the diagonal spots are carried from the half breadth to the body plan, do not as yet correct the timbers by them, but get in vertical longitudinal sections in the sheer plan, called buttock lines in after body, and perpendiculars forward. To obtain these, take the heights from the base in the body plan, upon the lines already got in for constructing the midship section, and transfer them to the sheer plan. For the endings forward, set off the breadths or distances of these perpendiculars, from the middle line in the body, upon the half breadth plan (as these lines cut the body in a fore and aft direction); square up the intersections of these lines with the top breadth to the corresponding sheer line, and there end the perpendicular section.

In the after body, strike in the same breadths across the margin of the wing transom, in the half breadth plan, and square up the intersection to the margin in the sheer plan, observing the round down of the transom, which must be taken from the body plan, and set off to cross the squaring up. Here end the buttock line.

If the vessel has a round stern, or the bottom plank worked up to the counter, then end the buttock line upon the lower counter line, squaring up its intersection with the half breadth, as *b*, Plate II., fig. 4, to the counter in the sheer plan, as *b*, fig. 1.

These several proof lines being transferred back to the body plan, if they agree with one another, the body may be considered correct; if not, the constructor's judgment will decide which shall be altered. Too much care cannot be taken here, as the cant bodies, transoms, &c., are all deduced from the square body.

Proceed with the sheer plan by getting in the CUTTING DOWN LINE, which determines the depth of the throats of the floors. This depth being decided amidships according to the experience of the builder, it will necessarily be greater as they become more acute forward and aft. Upon the cutting down line, draw in the keelson, which is sometimes parallel to it, but may taper at both ends, and is connected with the dead-wood knees forward and aft.

The BEARDING LINE is next in order. It is, as before explained, the provision made for embedding the plank, and does away with the line of formation, or upper rabbet of the keel, with the fore rabbet of the stern post, and after rabbet of the stem. To obtain the bearding line, take the heights from the base, where the timbers in the body plan cut the half siding; set them up in the sheer plan, and pass a curve through them, ending it aloft at the after edge of the rabbet on the stem, if there be no bearding here; but if there be, then at such bearding point, as seen in Plate III., fig. 3, where the bearding aloft is the distance from the dotted arc in the half breadth plan, to the top breadth line, *d*. The same method of ending must be adopted in the after body, with a round or elliptic stern, at the intersection of the stern timber with the fore rabbet. This may be corrected by the level lines, where they strike the half sidings.

CANT BODIES.

The cant timbers are placed at both extremities of the vessel, and are vertical like those in the square body, but differ from them in being oblique to the middle line of the half breadth plan. This obliquity increases towards the extremities, to meet the varying form of the body. The disposition of these timbers may be familiarly illustrated by a door on its hinges; when opened square to the side of the room it represents a square timber;

when less than this, a cant; and the farther closing of it will represent the formation of the cant body, including the cant hause piece.

By thus canting the timbers, their planes or sides are brought nearer to a square with the form of the body, the conversion of timber is materially assisted, and the strength of the fabric increased.

The disposition of these timbers is shown in the half breadth plan, Plate III., fig. 3, where it will be seen that the heels are brought closer together. In sharp vessels the full siding may be maintained, as, by placing them close together, sufficient obliquity will be gained; but in full bodies, where it is necessary to cant them quicker, the double futtock, or foremost timber of each frame, may be tapered to half its siding below.

The cants may be laid off first by level lines, as Plate III. Take the distance from the middle line in the half breadth, in the direction of the cant, to the several water-lines, the top breadth, and all lines that are level or nearly so, and transfer them to the body. For the heights of the upper spots, square up the intersection of the cant, in the half breadth, with the several lines of top breadth, to the corresponding lines in the sheer plan, and transfer these heights to the body upon those already got in.. A curve through these spots will be the form of the cant. For its ending below, square up the intersection of the cant line with the half siding in the half breadth plan, to the bearding line in the sheer plan, Plate III., fig. 2; set up this height of bearding line on the middle line of the body. Now take the distance from the cant at middle line, in the half breadth plan, in its oblique direction, to the half siding, and set it off square from the middle line of the body, at the height before obtained. This will be its ending; and for the heeling against the dead-wood, strike a line from this spot upwards parallel to the middle line.

The cants should be proved by the buttock or vertical lines, by squaring up from the half breadth their intersections with the cants, to the corresponding lines in the sheer plan; transfer these spots to the body, drawing level lines; then in the cant direction in the half breadth, take the distance from the middle line to the fore and aft stations, and set them off in the body plan upon the levels before drawn in.

A more convenient and correct method, especially if only one be used, is by horizontal riband lines, or, as they are termed, level diagonals. These are represented in the half breadth, by taking the distances square from the middle line in the body, to where the timbers cross the diagonals, and setting them off in the half breadth plan, ending them as level lines where the diagonal cuts the rabbet in the body plan. From these lines the cant timbers may be obtained, by taking the distances from the middle line in the half breadth plan in the direction of the cant, to the several level diagonals. Then, take off these same intersections square from the middle line of the half breadth, distinguishing these by a sirmark. Carry these breadths to the body plan, and set them off square from the middle line, where the sirmark intersects the diagonal; continue the level of these intersections out to the other spot, by which it is to be crossed; this is the spot for the cant, which must be ended, both aloft and below, in the same way as when laid off by level lines.

The level diagonal spots on the floor will be marked on the moulds, representing the respective heads and heels.

It will be seen that a timber ended as above, would be brought to a sharp point, forming a wedge, which would tend, in the event of heavy striking, to force off the plank, besides being so thin that the fastenings would destroy it. A stepping of solid timber is therefore usually adopted, which is got in as another bearding line about two or three inches without the half siding, and treated as such throughout, and the timbers ended thereto.

The cant floor mould is battened, having a middle board, the breadth of the keel, and the two side pieces made separate and hinged thereto, to enable it to fall to its proper place when moulding the piece. The cant of the timber for siding is obtained from its direction in the half breadth plan, and a cross mould made to this, with its seating square from the middle to the half siding of the keel.

TRANSOMS.

The transoms take their form from the buttocks, and are laid off as level lines, or canted to meet the form of the body, to attain the same advantages as are derived from canting the timbers.

The wing transom has, as already described, its upper side level at the seat, with a round down at the ends, and a round forward at the after edge. The margin of the transom is trimmed to the bevelling of the seat against the stern post.

The second and following transoms, when level, are struck in upon the sheer plan: their siding is graduated, the lower one being about two-thirds of the wing, and the openings from one-third the siding aloft, to the whole siding between the lower ones.

Represent the transoms in the body and sheer plans, producing the moulding edge in the latter to a perpendicular abaft the post. Provide a place for the plan of the transoms, the base of which will represent this perpendicular, and in which the inner rabbet, half siding, and buttock lines will be shown. Take the distances from the perpendicular in the sheer plan to the middle rabbet and bearding line and to all the buttock lines, and set them off upon the corresponding lines in the plan of the transoms.

The cant fassion piece must now be laid off, which is simply a cant timber, with its aft or moulding edge faced on upon the fore side of the wing transom only so far as its moulding will cover, as *a b*, Plate IV., fig. 3, and the heel at a suitable distance from the stern post, as *c* ; the nearer it is, the shorter will be the lower transoms, which are difficult to obtain. There is in large ships a second and sometimes a third fassion piece, shifting each other, and shortening the transoms the amount of their sidings. The transoms may be proved by taking them off as level lines from the body, and carrying them to the plan of the transoms.

If the transoms are canted, the lower ones are generally more so than the upper ones, to meet more exactly the varying form of the buttocks. Exhibit the cant transoms in the sheer plan, as marked *d e*, Plate IV., fig. 2. Take the distances from the perpendicular at the point *d*, in the direction of the transom, to the centre and fore part of the rabbet, the bearding, and buttock lines, and carry them to their respective lines in the plan of the transoms.

To prove this curve, take the heights in the sheer plan, where the transom cuts the rabbet, bearding and buttock lines, square timbers and fassion piece; transfer these heights to the corresponding lines in the body; a curve through these will show the disposition of the transom. Take the distances along the transom, from the point *d* in the sheer plan, to each of the lines before mentioned, and set them off in the plan of the transoms upon the perpendicular or middle line, drawing lines from them parallel to the base. Now take the breadths square from the middle line of the body to where the disposition of the transoms cuts the timbers, and square fassion piece, and set them off on the parallel lines in the plan of the transoms just got in. These spots should fall on the transom, before drawn in, if all be correct.

To obtain the length and end of the transom to which the mould is to be cut off, square up from the half breadth plan the intersection of the fassion piece with the middle line, to the line of the transoms, *d e*, in the sheer plan, and carry the height of *e* to the middle line of the body plan, as *f*. Then, where the disposition of the transom cuts the square fassion piece, level it out to the cant fassion piece; and from the point of intersection *a*, to the height *f*, on the middle line, draw a line which is to be marked on the fassion piece mould for the station and direction of the transom. Take the distance from the perpendicular in the sheer plan in the direction of the transom to *e*, where it cuts the squaring up of the heel of the fassion piece, and set it off from the base on the middle line of the plan of the transoms, and from this spot, *b*, to that obtained for the square fassion piece, draw a line, *f b*, at which the transom is to be cut off.

We may further prove the length of the transom by taking the distance in the body plan in the direction of the line for crossing the mould to the cant fassion piece, and setting it off upon the line just got in for cutting off the transoms in the plan of the transoms. This should correspond with the end spot already obtained.

ROUND AFT TUCK.

This forms a circular termination of the after body, but is attended with so much waste of timber, labour, and time in the mould loft, that the author deems it only worthy of being consigned to oblivion, especially as it is for all practical purposes superseded by the

SQUARE TUCK.

This is a thwartship termination of the after body, used only in small craft, being a substitute for the ordinary arrangement of transoms, &c. Strike in the after edge of the tuck from the after rabbet, Plate V., fig. 2, at *a*, to the sheer at *b*. This may be in a line with the rabbet, or more raking, as here shown, which reduces the angle with the counter, and gives a more airy appearance. It may be terminated at the seating of the counter, or run up to the sheer, as in lighters, &c.

Sufficient proof timbers having been laid off, run in a number of level lines, as marked 1 to 7, and lay them off in the half breadth plan, where as yet they have no ending, but must be projected as far abaft the aftermost station as may be necessary. Now square down from the sheer plan the intersections of the levels with the tuck to their corresponding lines in the half breadth plan, as *a a*, *b b*, &c. These will be the endings, the several breadths of which must be transferred to the corresponding levels in the body plan, which will give the projection of the tuck. This, however, is not the line to which the mould is made; to obtain which, take the distance upon the raking tuck in the sheer plan, from the point *a* to all the level lines, wale and top height, and set them off upon the middle line in the body, from the seating of the tuck. Strike these through the body plan, as levels, and square up the intersections of the projection with the original levels to those last got in; a curve through these spots is the line to which the mould is made, ending at the inner rabbet.

The diagonals which cross the tuck are ended by transferring the height where they cut the projection in the body plan, to the after edge of the tuck in the sheer plan. Square this down to the middle line in the half breadth plan; then take the distances from the middle line in the body plan, in the direction of the diagonal to the projection, and set it off in the half breadth upon the base just squared down.

The buttock lines are ended by transferring the height where they cut the projection in the body plan, to the after edge of the tuck in the sheer plan.

HAUSE TIMBERS.

Those hause timbers which have the sides fore and aft are represented in the body and half breadth plans, parallel to the middle lines at the breadth, as named, Plate III., figs. 1 and 3. Where the line cuts the levels in the half breadth plan, as in *p*, square up the intersections to the levels in the sheer plan, *p*. Where it cuts the level diagonals, in the half breadth plan, as *n*, square up the intersections in the sheer plan to the height of its intersection with the diagonal in the body plan, as *o*. Proceed in the same way with the main and top breadth lines; and to a curve through these spots the mould will be made.

BEVELLINGS.

Bevellings are the angles formed by the plane or outer surface of every timber with its moulding side. Those of the square timbers may be obtained in the following manner, as the most correct:

Strike in the sidings of the timbers, and lay off these bevelling edges in the same way as the moulding edge. Take the distance between the two edges, at all the heads and sirmarks, wale and top breadth lines, and set these off within or without a square, upon a board whose breadth is the siding of the timber.

A shorter method, and sufficiently correct for practice, is, to provide a board the breadth of the room and space, draw a square line across it, and upon one edge set off the distances of the timbers from one another taken from the body plan; lines from these spots to the square line on the other edge of the board will be the bevelling required. The under bevellings should be taken from the dead-flat, going forward and aft; the standing bevellings from the foremost and aftermost timbers, going towards dead-flat.

BEVELLINGS OF THE CANT BODIES.

Strike in the siding of the cant timbers in the half breadth plan, as Plate III., fig. 3, and square up the point M from the moulding edge of the cant, to the siding at *n*. Proceed to lay off the bevelling edge of the cant, in the body plan, in the same manner as the moulding edge, except that the distances in the direction of the cant must be taken from the point *n*, instead of the middle line. To end the bevelling edge, square up the point where it cuts the half siding of the deadwood, in the half breadth plan, to the bearding line in the sheer plan; and transfer the height of this intersection to the body plan. For the squaring of the heel *n*, take the distance to the half siding, and set this off from the middle line in the body plan, upon the line just levelled out. This will be the ending of the bevelling edge, the form of which may now be drawn in; and the bevellings of the timber may be obtained by taking the distance between the two edges at the several heads and sirmarks, and setting them off upon the bevelling-board, within or without a square, as the bevelling edge may be nearer to the middle line than the moulding edge, or more distant from it.

For the bevelling of the heel on the stepping, square up the cant timber from the middle line in the half breadth plan, to the bearding line in the sheer plan. Transfer this height to the middle line in the body plan, and from this point draw a line to the end of the moulding edge, which will be the direction of the stepping.

BEVELLINGS OF THE TRANSOMS.

The level transoms are bevelled by laying off the lower edge, and taking the distances between this and the moulding edge, setting it off upon a board, whose breadth is equal to the siding of the transom. The ends to be against the fassion piece are square.

The bevellings may also be taken from the buttock lines in the sheer plan, at their intersections with the several lines.

The cant transoms are bevelled as cant timbers, by striking in the siding of the transom below, and parallel to, the moulding edge in the sheer plan, and squaring down its intersection with the perpendicular, as *d* to *f*; and from *f* take the distances to the rabbets, bearding, and buttock lines, &c., and lay them off as before in the plan of the transoms, obtaining the end in the same way as before. The distance between the moulding and bevelling edges of the arm and end, is the bevelling.

BEVELLINGS OF THE HAUSE PIECE.

These are obtained by laying off the distances at any given siding, between the two edges, and setting them off on a board, as before directed.

BEVELLINGS OF THE SQUARE TUCK.

These are obtained by setting off the thickness or siding of the tuck in the sheer plan, as *c d*, Plate V.; then square up its seating to the siding, and from the point *c*, in the direction of the tuck, take the heights to the level lines, wale and top heights; set these off in the body plan from the seating, drawing a new set of level lines through them, as shown by the short dots. Now square down the intersections of the levels in the sheer plan with the fore side of the tuck, to the corresponding lines in the half breadth plan, and transfer all the distances of these spots from the middle line to the short dotted levels last got in in the body plan. Produce the fore side of the tuck down to the bearding, as *e*, and carry the height of this intersection to the half siding in the body plan. A curve through the spots before obtained, ending here, will give the fore side of the tuck for countermoulding and bevelling.

TO LAY OFF THE SIDE COUNTER TIMBER.

The projection of this timber has already been got in in the sheer plan; but this is not the line to which the mould is made; to obtain which proceed as follows:—

Draw in a sufficient number of level lines at the wing transom, upper and lower knuckle, sheer, and intermediate distances, ending them in the half breadth plan, by squaring down their intersections in the sheer. Now set off the fore edge of the timber in the sheer plan at the moulding determined on, square down its intersections with the levels to the corresponding lines on the half breadth plan; then run off both edges in the body. Next draw the line A B, to represent the plane of the mould, which is made to incline inwards at the upper part; remembering to equalize the spilings as much as possible, and especially to reduce the lower ones. Proceed to expand the timber in the sheer plan, by taking the distances of the levels from the base in the body plan, in the direction of the mould A B, and set them up vertically in the sheer plan, drawing level lines through the timber, as C D. Square up the original intersections of the two edges with the levels, to the raised levels just got in; these squarings up will give the points for the line to which the mould is made. Mark all the new levels on the mould, and proceed to take the spilings in the body at each level, at the fore and after edges, writing them on the mould.

For the heel of the timber on the transom, in a fore and aft direction, draw a level line at the upper side of the wing transom; the base of the sheer plan will be sufficient. For the heel against the fassion piece, square up the after edge of the fassion piece into the sheer plan, and at the intersection of this projection with the timber, draw a line inclining a little forward at the upper part, according to the inclination in expanding the edges; this will be the ending sufficiently near for practice. A perpendicular line will generally answer the purpose.

The bevellings for the right aft side, or round aft of the timber, are taken from a line drawn from the ending of each level line in the half breadth plan, parallel to the middle line; placing the stock of the bevel on the fore and aft line, and the tongue to the siding of the timber on the horizontal round forward.

For the bevelling of the round up, place the stock of the bevel, in the body plan, on the line A B, representing the plane of the mould, and let the tongue lie on the horizontal round up. When applied in moulding the piece, the stock of the bevel must be kept square to the level line marked on the mould. This process will be required for each knuckle, and the heel of the timber on the transom.

The bevelling of the heel against the fassion piece (which is always standing), is equal to that of the fassion piece with the middle line reversed, and is taken from a fore and aft line, to the side of the fassion piece. When applied to the piece, the stock of the bevel must be kept parallel to the levels marked on the mould.

CHAPTER V.

ON THE CALCULATIONS USUALLY PERFORMED IN DESIGNING A SHIP.

After a draft has been completed, it is desirable to ascertain by calculation whether the ship will be suitable to the service intended, as regards stability, burthen, and draft of water. For this purpose we must find the position of the centre of gravity, as the measure of stability; and her displacement—that is, the quantity of water which she will remove, or displace, when immersed to any given depth—in order to judge whether she will have sufficient capacity.

To find the position of the centre of gravity, we must first find the centres of the several planes, represented by the water-lines. These are divided by the lines representing the timbers into five parts, whose centres must all be found separately; namely, that between the after part of rudder and the aftermost station; that between this station and dead-flat; that between dead-flat and the timber next before it, which, as before explained, is less than the others; that between this timber and the foremost; and that between the foremost station and the fore part of stem. The centres of all these planes will, of course, be in the middle line of the vessel, and we may therefore use the half breadths instead of the whole breadths, as being more convenient. The spaces before and abaft the extreme stations may, with sufficient accuracy in practice, be considered as triangles, whose centres, therefore, will be at one-third of the length from the station, and whose half area will be equal to the length, multiplied by half the half breadth. The space between dead-flat and the next station, being a parallelogram, its centre will be midway between them, and its half area will be equal to its length multiplied by the half breadth. To find the centres and areas of the remaining two planes, take the half breadths at every fourth station (which will be sufficiently accurate in practice), excepting the extreme stations of each plane, of which take only the half, and multiply them by the numbers, 1, 2, 3, &c., according to their distance from the aftermost station of each plane. Divide the sum of these products by the sum of the half breadths, the quotient will be the distance of the centre of gravity of the plane from the aftermost station. Multiply the sum of the breadths by the distance between the stations, and the product will be the area. Now, to find the centre of the whole water-line, multiply the area of each of these five planes by the distance of its centre from the aft side of rudder; the sum of these products, divided by the sum of the areas (or entire half area of the water-line), will give the distance of the centre from the aft side of the rudder.

Proceed in the same way to find the centres and areas of as many water-lines as may be judged necessary; these must be equidistant from one another, and from the upper side of the keel. Find also the centre of the upper surface of the keel, including the stem, stern post and rudder, which, of course, will be in the centre of the length, and its half area, which is found by multiplying the length by the half breadth.

Now, to find the longitudinal position of the centre of gravity of the immersed body, take the areas of each of the several planes, except the upper and lower ones, of which take only the half, and multiply by the distance of their respective centres from the aft side of rudder; the sum of these products, divided by the sum of the areas, will give the distance of the centre of gravity of the whole bottom from the aft side of rudder.

For the height of the centre of gravity, multiply the areas of the several planes (taking only half of the upper and lower ones) by the numbers 1, 2, 3, &c., as they recede from the upper side of keel; divide the sum of these products by the sum of the areas, and the quotient, multiplied by the distance between the water-lines, will give the height of the centre of gravity above the upper side of keel.

The following calculation of the centre of gravity of the cutter of 195 tons, Plate VI., will more fully explain the method of performing the whole operation. A scale divided into tenths of feet, instead of inches, is here used, and will be found very convenient in all such calculations :—

FIRST, OR UPPER WATER-LINE.

PLANE ABAFT 16.*

Length, 8.3 ÷ 3 = 2.8 from station, or 5.5 from rudder.

Area, 8.3 × 2.3 = 19.0.

PLANE BETWEEN 16 AND DEAD-FLAT.

Half 16 = 2.3 × 0
12 = 8.3 × 1 = 8.3
8 = 9.9 × 2 = 19.8
4 = 10.5 × 3 = 31.5
Half ⊕ = 5.4 × 4 = 21.6
36.4 81.2
8 8
Area, 291.2 36.4)649.6(17.8 C. of G. from 16.

PLANE BETWEEN ⊕ AND B.

Length, 3 ÷ 2 = 1.5 distance of centre from ⊕.

Area, 3 × 10.5 = 31.5.

PLANE BETWEEN B. AND S.

Half B 5.4 × 0
F 10.4 × 1 = 10.4
K 9.3 × 2 = 18.6
O 6.8 × 3 = 20.4
Half S 1.2 4 = 4.8
33.1 54.2
8 8
Area, 264.8 33.1)433.6(13.1, centre from B.

PLANE BEFORE S.

Length, 4.5 ÷ 3 = 1.5, distance of centre before S.

Area, 4.5 x 1.2 = 5.4.

Then	Area.	Distance of Centres from aft side of Rudder.	Products.
Plane abaft 16.	19.0 ×	5.5 =	104.5
16 to ⊕	291.2 ×	(8.3 + 17.8) = 26.1 =	7600.3
⊕ to B	31.5 ×	(8.3 + 32 + 1.5) = 41.8 =	1316.7
B to S	264.8 ×	(8.3 + 32 + 3 + 13.1) = 56.4 =	14934.7
Before S	5.4 ×	(8.3 + 32 + 3 + 32 + 1.5) = 76.8 =	414.7
Half Area,	611.9		24370.9

Then 611.9)24370.9(39.8, distance of centre from aft side of rudder.

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* As only every fourth station is here taken, the timbers 18 and 19 cannot be included n the calculation of the larger plane.

SECOND WATER-LINE.

PLANE ABAFT 16.

Length, 8.8 ÷ 3 = 2.9 from station, or 5.8 from rudder.
Area, = 8.8 × 1.2 = 10.5.

PLANE BETWEEN 16 AND ⊕.

Half 16 1.2 × 0
12 6.2 × 1 = 6.2
8 8.8 × 2 = 17.6
4 9.9 × 3 = 29.7
Half ⊕ 5.2 × 4 = 20.8
31 3 74.3
8 8
Area, 250.4 31.3)594.4(18.9, distance of centre from 16.

PLANE BETWEEN ⊕ AND B.

Length, 3.0 ÷ 2 = 1.5 distance of centre from ⊕.
Area, = 3.0 × 10.5 = 31.5.

PLANE BETWEEN B. AND S.

Half B 5.2 × 0
F 9.7 × 1 = 9.7
R 8.3 × 2 = 16.6
O 5.7 × 3 = 17.1
Half S .9 × 4 = 3.6
29.8 47.0
8 8
238.4 29.8)376.0(12.6 distance of centre from B.

PLANE BEFORE S.

Length, 4.4 ÷ 3 = 1.4 distance of centre from S.
Area, = 4.4 × 9 = 3.9.

Then,

	Area.	Distance of Centres from aft side of Rudder.	Products.
Plane abaft 16	10.5 ×	5.8 = . . .	60.9
Between 16 and ⊕	250.4 ×	(8.8 + 18.9) = 27.7 = .	6936.0
Between ⊕ and B	31.5 ×	(8.8 + 32 + 1.5) = 42.3 =	1332.4
Between B and S	238.4 ×	(8.8 + 32 + 3 + 12.6) = 56.4 =	13445.7
Before S	3.9 ×	(8.8+32+3+32+1.4) = 77.2 =	301.0
Half Area,	534.7		22076.0

And,

534.7)22076.0(41.2 distance of centre from aft side of rudder.

THIRD WATER-LINE.

PLANE ABAFT 16.

Length, 9.2 ÷ 3 = 3.1, or 6.1 distance of centre from aft side of rudder.

PLANE BETWEEN 16 AND ⊕.

Half 16 .6 × 0
12 3.5 × 1 = 3.5
8 6.2 × 2 = 12.4
4 7.8 × 3 = 23.4
Half ⊕ 4.3 × 4 = 17.2
22.4 56.5
8 8
Area, 179.2 22.4)452.0(20.1 distance of centre from 16.

PLANE BETWEEN ⊕ AND B.

Length, 3 ÷ 2 = 1.5 distance of centre from ⊕.

Area, 3 × 8.6 = 25.8.

PLANE BETWEEN B. AND S.

Half B 4.3 × 0
F 7.8 × 1 = 7.8
K 6.5 × 2 = 13.0
S 4.3 × 3 = 12.9
Half O .5 × 4 = 2.0
23.4 35.7
8
23.4)285.6(12.2 distance of centre from B.

PLANE BEFORE S.

Length, 4 ÷ 3 = 1.3 distance of centre from S.

Area, 4 × 5 = 2.0.

Then,

	Areas.	Distance of Centres from aft side of Rudder.	Products.
Plane abaft 16	5.5	× 6.1 . .	33.5
Between 16 and ⊕	179.2	× (9.2 + 20.1) = 29.3 = .	5250.5
Between ⊕ and B	25.8	× (9.2 + 32 + 1.5) = 42.7 =	1101.6
Between B and S	187.2	× (9.2 + 32+3+12.2) = 56.4 =	10558.0
Before S	2.0	× (9.2+32+3+32+1.3) = 77.5 =	155.0
Half Area,	399.7		17098.6

And,

399.7)17098.6(42.7, distance from aft side of rudder.

FOURTH WATER-LINE.

PLANE ABAFT 16.

Length, 9.3 ÷ 3 = 3.1, or 6.2, distance of centre from aft side of rudder.

PLANE BETWEEN 16 AND ⊕.

Half 16 .3 × 0
12 1.3 × 1 = 1.3
8 3.0 × 2 = 6.0
4 4.5 × 3 = 13.5
Half ⊕ 2.5 × 4 = 10.0

11.6 30.8
8 8

92.8 11.6)246.4(21.2, distance of centre from 16.

PLANE BETWEEN ⊕ AND B.

Length, 3 ÷ 2 = 1.5, distance of centre from ⊕.

Area, 3 × 5 = 15.

PLANE BETWEEN B. AND S.

Half B 2.5 × 0
F 4.5 × 1 = 4.5
K 3.7 × 2 = 7.4
O 2.4 × 3 = 7.2
S .5 × 4 = 2.0

13.6 21.1
8 8

108.8 13.6)168.8(12.4, distance of centre from B.

PLANE BEFORE B.

Length, 3.6 ÷ 3 = 1.2, distance of centre from S.

Area, 3.6 × 5 = 1.8.

Then,

	Areas.	Distance of Centres from aft side of Rudder.	Products.
Plane abaft 16	2.7 ×	6.2 = . .	16.7
Between 16 and ⊕	92.8 ×	(9.3 + 21.2) = 30.5 = .	2830.4
Between ⊕ and B	15.0 ×	(9.3 + 32 + 1.5) = 42.8 =	642.0
Between B and S	108.8 ×	(9.3 + 32 + 3+12.4) = 56.7 =	6168.9
Before S	1.8 ×	(9.3+32+3+32+1.2) = 77.5 =	139.5
Half Area,	221.1		9797.5

And,

221.1)9797.5(44.3, distance of centre from aft side of rudder.

UPPER SIDE OF KEEL.

Length (including rudder), 78.4 × 4 (the half breadth), gives 31.3 for the half area.

And 78.4 ÷ 2 gives 39.2, distance of the centre from aft side of rudder.

To find the longitudinal position of the centre of gravity of the whole immersed body, we have now only to multiply the area of each water-line (except the upper and lower, or upper side of keel, of which take only the half), by the distance of their respective centres from the aft side of rudder; or, which is the same thing, take the sum of the products of the planes of which they are composed, and divide the sum of these products by the sum of the areas.

Thus,

	Areas.	Products.
Half the first Water-line,	305.9	12185.4
Second Water-line, .	534.7	22076.0
Third Water-line, .	399.7	17098.6
Fourth Water-line, .	221.1	9797.5
Half of area of Keel, 15.6 × 39.2	15.6	611.5
	1477.0)	61769.0(41.8, distance of centre of gravity from aft side of rudder.

FOR THE HEIGHT OF THE CENTRE OF GRAVITY.

	Areas.	Products.
Half of the upper side of Keel,	15.6 × 0	
Fourth Water-line, .	221.1 × 1	221.1
Third Water-line, .	399.7 × 2	799.4
Second Water-line, .	534.7 × 3	1604.1
Half of the First Water-line,	305.9 × 4	1223.6
	1477.0	3848.2

Then, 1477.0)3848.2(2.6

And 2.6 × 2.05, the distance between the water-lines, gives 5.3 feet, the height of the centre of gravity above the upper side of keel.

ON DISPLACEMENT.

By displacement we mean the quantity of water which a ship will remove or displace, when immersed to a given water-line. This, of course, will be equal to her entire depth, and consequently, by calculating the solid contents of the immersed body, and allowing sixty-four pounds as the weight of a cubic foot of salt water (or thirty-five feet to the ton), we obtain the weight of the ship; and if this operation be performed both for the load and light water-lines, the difference between the two results will be the weight of armament or cargo that she will carry. Or, conversely, the weight of the ship being ascertained by a computation of all the materials employed in the construction (allowing fifty pounds as the average weight of a cubic foot of timber for the hull, and forty pounds for the decks, masts, and spars), we may ascertain what water she will draw, and judge whether the ports or gunwale will be at a suitable height above the water.

To find the solid contents of an irregular figure like a ship's bottom, we have only to add together the areas of a sufficient number of water-lines (taking only half the upper and lower ones), and multiply by the distance between them. But as this operation has already been performed in finding the centre of gravity, we have only to multiply the sum of the half areas by 2, and by 2.05, the distance between the water-lines, and add the contents of the keel; the result, divided by 35, the number of cubic feet to a ton of salt water, will give the whole displacement.

Thus,

1476, sum of half areas
Multiplied by 2
2952
And by 2.05, distance between water-lines
14760
59040
6051.60
Keel, 78.4, × 8 × 1.3 81.53
Divide by 35)6133.13(175.23 tons,

which is the displacement, or weight of the vessel when immersed to the upper water-line.

As the draft of water of every ship is continually varying, it will be convenient to construct a scale, showing the displacement at any degree of immersion, as in Plate VI.; to construct which, proceed as follows:—

First, divide the contents of the keel, in feet, as already found, by 35, which will give its displacement in tons. Set up the depth of the keel, to any scale, on a line perpendicular to a base, and the displacement on a level at this height. Now, add together the half areas of the upper side of keel, and lower water-line (which are already found),* and multiply by the distance between them; add the contents of the keel in

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* When it is desired only to find the displacement, without calculating the position of the centre of gravity, the student will see at a glance what parts of the operation may be omitted.

feet, and divide the sum by 35; the product will be the displacement of the ship when immersed to this water-line, which must be set off, as before, on a level corresponding to the height of the water-line. Proceed in the same way with as many water-lines as may be considered necessary, up to the load water-line, adding the half areas of each two adjacent ones, multiplying by the distance between them, and adding the contents of the part below, as already calculated; this divided as before by 35, will give the displacement in tons to that water-line, which must be set off as above directed. A curve through the several spots thus obtained will show at a glance the displacement of the vessel at any draft of water.

Thus,

Keel, 78.4 × 8 × 1.3 = 81.53
And 35)81.53(2.33 tons, displacement of keel.

Half area of keel,	31.36
Half area of fourth water-line,	221.10
	252.46
Multiply by distance between,	2.05
	517.54
Add contents of keel,	81.53
	35)599.07(17.11 tons, displacement to fourth water-line.
Half area of fourth water-line,	221.1
Half area of third water-line,	399.7
	620.8
Multiply by distance between,	2.05
	1272.64
Add contents below fourth water-line,	599.07
	35)1871.71(53.47 tons, displacement to third water-line.

Half area of third water-line,	399.7
Half area of second water-line,	534.7
	934.4
Multiply by distance between,	2.05
	1915.52
Add contents below third water-line,	1871.71

35)3787.23(108.2 tons, displacement to third water-line.

Half area of second water-line,	534.7
Half area of third water-line,	611.8
	1146.5
Multiply by distance between,	2.05
	2350.32
Add contents below second water-line,	3787.23

35)6137.55(175.35 tons, displacement to the fourth, or load water-line.

ON THE METACENTRE.

The metacentre is a point below which the centre of gravity or displacement must come, in order that the vessel may retain her position; since, if this centre come above it, she will have a tendency to upset; and the distance between these two points may be considered as a measure of the stability.

The supporting power of a fluid may be considered as acting in a vertical line passing through the centre of gravity of any immersed body. Let A B (Plate V., fig. 7) represent the water-line of a vessel, when upright, and C, the centre of displacement, which, of course, will be in the middle line of the vessel. Now, suppose the ship to be inclined on one side without affecting her displacement; let D E be the water-line when inclined, and F the centre of gravity of the inclination. Join C F, and draw a line from F perpendicular to C F or D E; then the point G, where this perpendicular intersects the middle line, is the metacentre.

The investigation of the theory of the metacentre requires a knowledge of the higher branches of the mathematics, and cannot, therefore, be entered upon in a work like the present; but we shall endeavour to give sufficient directions to enable the student to ascertain its position.

Take the half breadths at the several stations on the load water-line, as already measured, and cube them all separately, except the station before dead-flat. Add all these cubes together, and multiply by the distance between the stations. Now cube the half breadth of the station before dead-flat, and multiply by the distance between these two; add all these results together, and divide two-thirds of the sum by the whole displacement of the ship as already found, which will give the height of the metacentre above the centre of gravity of displacement.

Thus,

Half breadths.		Cubes.
S	2.4	13.824
O	6.8	314.432
K	9.3	804.357
F	10.4	1124.864
B	10.8	1259.712
4	10.5	1157.625
8	9.9	970.299
12	8.3	571.787
16	4.6	97.336

6314.236

Multiply by distance between, 8

50513.888

Cube of $\oplus = 1259.712 \times 3$, . 3779.136

54293.024

2

3)108586.048

6137.55) 36195.349(5.8 feet,
height of metacentre above the centre of displacement.

CHAPTER VI.

ON STEAM NAVIGATION.

SCIENCE has been called the handmaid of religion; a sentiment far more philosophical than another which has obtained extensive currency, namely, that civilization is necessarily the forerunner of Christianity. But whatever supremacy we may be desirous of giving to religion, we cannot attach too great importance to those arts and sciences which are calculated to promote the intercourse of nations, and its attendant benefits. If we mistake not, steam navigation has taken upon itself the mighty task of bringing about this great blessing. Much has been done by ordinary commerce, and still more by printing; but by means of steam navigation, distance has been well-nigh annihilated, and exchanges made of the commodities of different countries, which practically demonstrate the mutual dependence of all mankind, and the advantages of social and commercial intercourse.

We dare not anticipate a limit to the progress of this blessing; but one short generation has been sufficient to invent, or, at least, practically to apply, the science of steam navigation, and the whole globe is now embraced in its gigantic grasp. Its universal adaptation to all the necessities of commerce, its applicability to seas, however rough, or to rivers, however shallow, must lead every well-wisher to mankind earnestly to desire its complete maturity and its wide extension. But, if ship building, in general, has hitherto scarcely been treated as a science; if now, for the first time, the genius of the mathematician, and the experience of the practical man, are united in extensive experiments upon the building of sailing vessels, we may reasonably expect to find this new and amazing extension of the art attended with much difficulty and many errors. We cannot but hope that, by the patient and careful combination of theory with experience, it will speedily be brought to great perfection, especially when we consider the unparalleled rapidity with which it has hitherto advanced. It is not more than thirty years since the first steam vessel was constructed, by Miller and others, in Scotland; and less than that time since the first sea-going steamer was started by Stephens, in America, upon principles, however, directly and unequivocally derived from the inventors on the Clyde. Improvements, too, have progressed as rapidly as its application, both in the form of vessel, and in the construction of the engines. The propelling power, too, has received various improvements; and while the paddle wheel has been greatly increased in efficiency, the screw propeller is likely to supply a long-felt desideratum, dispensing with the cumbrous paddle-boxes, and keeping the motive power always in a position of safety and efficiency, notwithstanding the constant alterations in the immersion of the vessel.

The form of body best adapted for steam vessels, is a primary consideration. It will be found that most of the principles which constitute a good sailing ship, will also apply to a steamer. We have repeated instances, in which first-class steam ships that have afterwards proved of superior character, have gone as fast, under jury rig, and with not more than half the momentum of canvass allotted to sailing ships of equal tonnage, as they have subsequently gone under the full power of the engines. Many valuable inferences may be drawn from this fact; and we unhesitatingly bring to our aid, in building steam ships, the whole experience of the profession, to a much greater extent than was at first adopted. Experience shows that the long bow and clean run are indispensable; for, whatever may be the laws of fluids, the great speed of river boats thus built, the increase obtained by lengthening so many of the earlier formation, and the increased acuteness of each succeeding class, amount to a demonstration on this point.

The breadth may be varied according to the service required. A narrow vessel, or midship section that occasions least displacement, is, doubtless, best for river purposes; but lateral oscillation is found to be the greatest obstruction to speed, particularly from the irregular immersion of the paddle wheels, which reduces their efficiency, and causes great discomfort to those on board. This oscillation, we think, is best prevented by increasing the breadth, and by an easy bildge, with the floor as flat as possible. Although the area of midship section is thus increased, which may seem at variance with what we have before stated, yet it will be found that the increased stability more than counterbalances the loss. Another means of promoting stability is the keeping the weight of the engines, and everything else, as low as possible.

The proportion of dimensions may likewise be varied in different circumstances. For quiescent waters, we may sacrifice the general principles of stability to speed and accommodation, and may have eight or ten times the breadth for the length, reducing thereby the draught of water, and the area of greatest section. But for sea-going vessels, which are required to carry a large armament, as in men-of-war, or large cargo, as in merchant ships, no greater length than six times the breadth can be admitted. Most of the steamers of the first class are of this proportion.* The depth may, with general advantage, be one-tenth of the length; or, more correctly, for 100 tons,

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* The ark in Scripture was of these proportions, namely, six times the breadth for the length, and one-tenth of the length for the depth. Other proportions may in particular circumstances promote speed; but for stability and security at sea, the proportions of the ark, destined as she was to endure the greatest commotion of waters the world has ever known, are, we fearlessly assert, infallible, since the experience of four thousand years has only confirmed them; a collateral evidence, at least, of the truth of the Scripture narrative. The ark was twice as long, and twice as wide and deep, as the West-India mail steamers, and consequently would make eight of them, considered as regular figures.

half the beam; for 500 tons, two-thirds; and above 1000 tons, three-fourths of the beam.

The next point to be considered, is proportion of power to register tonnage. The imperfect system of legal admeasurement prevents any correct rule being given; and the variation in the service required being considerable, no fixed principles can be laid down. Some time must elapse before this point is matured, inasmuch as the merchant in competition, and the naval architect in contending for precedency, are alike in danger of setting too great a value upon the single item of speed, regardless of other qualities which are absolutely essential. Small vessels are found to require the greatest proportion of power.

Our Government, at first, adopted a small proportion, but as they did not succeed in producing even a tolerable form of vessel, the remedy has been sought in a great increase of power.

We are mistaken if this succeeds, believing that the defect of most of the Government steamers lies not in the propelling power, but in the formation of the vessel. Some light has been thrown on this point, by the reports of the Experimental Squadron of May 1846. They sailed from Spithead with a strong east wind; the ships of the line went nine knots, and at this rate distanced the steamers, several of which were disabled, and put into Plymouth to refit. From this we think it may be seen that excessive power, involving increased weight of engines, water, and coals, has rendered these deep-laden vessels, rather than war-steamers, which, if efficient, are adapted to do more, in many respects, than ships of the line.

It would be unjust to compare our first-class war steamers with the corresponding grade of packet ships; the latter being equipped only for a month's voyage, and, in most cases, expecting to be little more than half that time upon it, while the other has a permanent and heavy armament and equipment. At the same time, such must be the occasional service required from a war steamer, that the greatest possible speed is often indispensable. The only solution of this difficulty seems to be the adoption of two classes of vessels for different services; we must have our light cavalry as well as our heavy horse, at sea as in the field.

Increased speed is an expensive attainment, whether in sailing vessels or those moved by any other power, from the known law of fluids, that resistance increases as the squares of the velocity. The best proportion of power to tonnage seems to be, one horse power to two tons of the entire register tonnage for vessels up to 800 tons; one to $2\frac{1}{4}$th up to 1500 tons, and one to $2\frac{3}{4}$ths for the largest class.

CHAPTER VII.

MISCELLANEOUS INFORMATION.

I. ON THE VARIOUS MEASUREMENTS OF SHIPS.

THE measurement of register tonnage, as formerly practised according to law, and still necessarily much used, from the complication of the new mode, was obtained by taking the length of keel and fore-rake at the height of bowsprit, and from this deducting 3-5ths of the main breadth, calling the residue keel for tonnage; this multiplied by the main breadth and half breadth, and divided by 94, gives the register tonnage. Example; for a ship of 60 feet long and 20 wide,—

$$\begin{array}{rl} & 60 \\ \text{3-5ths of 20,} & \underline{12} \\ & 48 \times 20 \times 10 = 9600, \div 94 = 102\tfrac{12}{94}\text{ths.} \end{array}$$

For ships of war the length is taken between the perpendiculars from the fore part of the stem at the height of the hause holes, to the after part of the post to the wing transom, deducting $2\frac{1}{2}$ inches to the foot for the height of the transom; and 3-5ths of the residue is keel for tonnage.

Builder's measurement, as used on the Thames, is the same as the above, except that 3 inches to the foot, instead of $2\frac{1}{2}$, are deducted, making a considerable difference against the builder as compared with the Customs' measurement.

Colliers are measured as other vessels for register tonnage, but are usually built and fitted by the keel, and calculated thus:—

Multiply the lengths of the keel alone, (not stem) by the extreme breadth, and the depth, and the product by 56, cutting off as many places of decimals as there are figures in the multiplicand. Example,—

Length,	.	66 feet
Breadth,	.	23
		1518
Depth,	.	12
		18216
		56
		10.20096 keels.

For a very full vessel, multiply by 58. The tonnage, according to the new measurement, given below, divided by 14, or $13\frac{3}{4}$ths, for very full vessels, gives the number of keels.

The new mode of measurement, as by law established, is a most complicated and inefficient method, which is liable to evasion, and cannot be applied after a vessel is fitted with bulkheads and cabins. It is performed as follows:—Take the length aloft, from the inner side of the stem or apron to the fore side of post; the depths at 1-6th, 3-6ths, and 5-6ths of this length; the breadths at these three stations, the foremost and aftermost at 1-5th and 4-5ths of the depth, and the centre at 2-5ths and 4-5ths; take also the length at half depth, from the aft side of apron to fore side of deadwood knee; these worked together, as shown in the following examples, and divided by 3500, give the tonnage.

Example of a vessel of $189\frac{3340}{3500}$ tons:—

DEPTHS AT THE THREE STATIONS.

Foremost		Middle.			Aftermost.	
Ft.	In.	Ft.	In.		Ft.	In.
15	1	14	10		14	7
			2			
		29	8	twice middle depths.		
		15	1			
		14	7			
		ft. 59	4			

BREADTHS AT THE SAME STATIONS.

Ft.	In.		Ft.	In.		Ft.	In.	
17	8	at 1-5th	21	7	at 2-5ths	7	1	at 4-5ths
9	9	at 4-5ths		3			2	
27	5	sum of bdths.	64	9		14	2	
			18	10	at 4-5ths	17	7	at 1-5th
			83	7	sum of middle breadths.	31	9	
			27	5	do. foremost do.			
			31	9	do. aftermost do.			
			142	9	Total sum of breadths.			
					Length at half depth.	78	6	

SUM.

Ft. In.
142 75 total sum of breadths.
59 33
42825
42825
128475
71375
8469.3575
78.5
423467875
677548600
592855025
3500)664844.56375($189\frac{3344}{3500}$ tons.
3500
31484
28000
34844
31500
3344

II.—ON THE SLIDE RULE AND TIMBER MEASURING.

The calculations by Gunter's, or the slide rule, are of logarithmic character, and by means of this instrument we may perform all the ordinary operations of arithmetic merely by inspection.

Multiplication. Set 1 on B against one of the multipliers on A; and the product will be found against the other, on B.

Division. Set the divisor on A to 1 on the slides, and seek the quotient against the dividend on A.

Rule of Three. Set the first term on the slides to the second on A, then against the third on B, seek the answer on A.

Extraction of the Square Root. Set the middle division, which is marked 1, on C, to 10 on D, and against the given number on C, will be the square root on D, on the left hand of the point 1, if the number of figures be even; and on the right, if it be odd.

To find the *eight square* of a square piece of timber, &c. This is 5-12ths of the size, therefore set 5 on the slide to 12 upon A, and against the whole size upon A, will give the eight square on the slide, which must be set off from the middle line. To find the eight square from the edge, perform the same operation for 7-12ths, and take half.

To find the tonnage of a ship by the old measurement. A vessel 13 feet $8\frac{3}{4}$ inches wide, is as many tons as there are feet in the keel for measurement; therefore set the keel for tonnage on the slide, to 13 $8\frac{3}{4}$ on D, and against the extreme breadth on the lower line, will be the tonnage on the slide.

TIMBER MEASURING.

To measure square timber, set the length on C to 12 on D, and against the size in inches on D will be the contents in feet on C. Example:—

50 feet × $8\frac{1}{2}$=25 feet contents.

If the breadth and depth be unequal, place the length on the slide to 12 on A, and against one of the sizes will be found the area of that surface; set this area to 12, as before, and against the other size will be the whole contents. Or extract the square root of the product of the sizes, thus:—Multiply the two sizes, suppose 8 and 18, by setting 1 on B to 8 on A, then 18 on the slide will cut 144, the product. To obtain the square root, set the middle division on C, which is 1, against 10 on D; then 144, as before obtained, upon C, will show the siding of the timber to be equal to 12 square, which, multiplied by the length, gives the contents. Observe, in finding the square root on C, if the number of figures be odd, it will be on the right hand of C, or the middle; if even, on the left.

We here see the error of adding together the two sides, and taking the mean, as frequently practised; this in the example here given would be 13, whereas the truth is 12.

Round or Girt Measure, is found by taking one-fourth of the girt with a string or tape, and dealing with it as square timber.

The subject of girting is worthy of particular attention. In irregular trees, the more girts are taken the greater will be the result. The variations in measuring a spar, or conical piece of timber, are remarkable. By the diagram, Plate II., fig. 6, it will be seen that above 9 feet may be cut off from the end, and the tree still measure the same; being callipered in both cases in the middle. The piece will be found to measure 8 feet, if the girt be taken in the middle of the length; 9 feet 3 inches, if it be measured in 2 feet lengths; while 6 feet cut off the but-end will measure more than either.

III.—RUDIMENTS OF ALGEBRA.

As in most of the works on ship building the various rules are couched in algebraical formulas, with which many practical men are unacquainted, it may be useful to give here some explanation of the terms usually employed in this science, and the elementary operations to be performed.

$+$ Plus, the sign of addition, called the positive sign.

$-$ Minus, the sign of subtraction, or negative sign. Every quantity in algebra must have one or other of these two signs prefixed to it, or before the first of several quantities $+$ is understood if no sign be expressed. When several quantities with different signs are placed together, those with $-$ signs may be considered as subtracted from the others, thus:

$$a+x-b+c+w-z.$$

means, the sum of a, x, c, and w, less the sum of b and z.

Any value may be assigned to each letter; a number placed before a letter is called its coefficient.

$\times$ Sign of multiplication; which, however, is more usually expressed by joining the quantities to be multiplied: thus, $a\ b$, means $a \times b$.

$\div$ Sign of division; which is oftener expressed by putting the dividend over the divisor: thus, $\frac{a}{b}$ means a divided by b.

$a+b$, or $(a+b)$ Quantities placed in a parenthesis, or as termed in algebra, a vinculum, thus, are to be treated as one quantity; thus, $(a+b)\ x$ means the sum of a and b multiplied by x, but $a+b\ x$ means b multiplied by x, plus a.

A small figure ^{2} over any quantity, thus, (b^2) signifies that it is to be squared or multiplied by itself. A figure ^{3}, in the same way, signifies that it is to be cubed, or multiplied twice by itself. In the same way any other figure signifies that the quantity is to be multiplied by itself once less than that number of times.

Observe, that if the quantity is joined to another, only the letter over which the figure is placed is to be squared.

$\sqrt{}\sqrt[3]{}$ signify the square and cube roots: that is, the number or quantity which, when squared or cubed, will produce the quantity to which these signs are prefixed.

$=$ means equal to.

Addition is performed by simply adding the coefficients of similar quantities that have similar signs, and prefixing the sign: if there be similar quantities of opposite signs, subtract the less from the greater, and set down the remainder only with its proper sign.

Subtraction is performed by placing either quantity under the other, supposing all its signs to be changed, and proceeding as in addition.

Multiplication is performed by multiplying the numbers, and adding the letters, thus,

$$(4ab+4c)\times -3d = -12abd - 12cd.$$

Observe, that like signs multiplied together produce +, and unlike signs —.

Compound multiplication is performed as in arithmetic; thus,

$$\begin{array}{rr}
 & 4ab+4c \\
 & 4ab-4c \\
\hline
 & -16abc-16c^2 \\
16a^2b^2+16abc & \\
\hline
16a^3b^2 & -16c^2
\end{array}$$

Here it will be seen that the $-16abc$ cancels the $+16abc$; and that when any letter is multiplied by itself, as c, the operation is expressed by putting the figure ^{2} over it, to indicate its being squared. If a square number is to be thus multiplied by the single number, it becomes cubed, by adding the indices (as they are termed).

$$a^2 \times a = a3; \text{ or, } a^2 \times a^2 = a^4 : a^2 \times a^3 = a^5$$

In *Division*, if the divisor and dividend consist of only one quantity, place the former underneath the latter, cancel any like quantities in both, and divide the co-efficients by the greatest number that will divide them both; thus,

$$\text{Divide } 4abc \text{ by } 2ac. \quad \text{Ans. } \frac{4abc}{2ac} = 2b$$

If the divisor be a single quantity, and the dividend consist of several terms, divide each term separately as above, observing, as in multiplication, that like signs produce +, and unlike signs —.

If both divisor and dividend consist of several terms, then arrange them both according to the powers of some one letter common to both, and divide the first term of the dividend by the first of the divisor; the result will be the first term of the quotient, by which multiply all the terms in the divisor, and subtract the product from the dividend; then to the remainder annex as many of the terms of the dividend as may be necessary, and find the next term of the quotient as before.

Example:—

Divide $a^4 - 4a^3x + 6a^2x^2 - 4ax^3 + x^4$ by $a^2 - 2ax + x^2$.

$$\begin{array}{l}
a^2 - 2ax + x^2)a^4 - 4a^3x + 6a^2x^2 - 4ax^3 + x^4(a^2 - 2ax + x^2 \\
\qquad\qquad\quad \underline{a^4 - 2a^3x + a^2x^2} \\
\qquad\qquad\qquad\quad -2a^3x + 5a^2x^2 - 4ax^3 \\
\qquad\qquad\qquad\qquad \underline{2a^3x + 4a^2x^2 - 2ax^3} \\
\qquad\qquad\qquad\qquad\qquad\quad a^2x^2 - 2ax^3 + x^4 \\
\qquad\qquad\qquad\qquad\qquad\quad \underline{a^2x^2 - 2ax^3 + x^4}
\end{array}$$

The same result would be obtained by arranging the terms according to the descending powers of x. If there be a remainder, it must be placed over the divisor as a fraction, and simplified as much as possible. It is to be observed, that the division of quantities in any power is performed by subtracting their indices; thus, $a^5 \div a^2 = a^3$.

ON EQUATIONS.

An equation consists of two algebraical expressions equal to each other, one or both of which contains an unknown quantity, of which it is required to find the value; thus,

$$2x + 5 = 11$$

is an equation in which it is required to find the value of x. In order to do this, it is to be observed, that we may transfer any quantity from one side of the equation to another, by changing the sign; we may multiply or divide both numbers by any number or quantity; may add or subtract any quantity from both numbers. We may also square or cube, or extract the square or cube roots of both, without altering the value of the equation. By a little practice we shall be enabled to apply any or all of these methods, as may be requisite. Thus in the simple equation just given :—

$$2x + 5 = 11$$
Transposing $2x = 11 - 5 = 6$
Dividing by 2 $x = 3,$

If there be fractions in the equation, they must be removed by multiplying them all by the denominators of all the fractions except their own, and then multiplying the whole equation by the denominator thus obtained, which will reduce all the fractions to simple quantities. Thus, to find the value of x in the equation.

$$\frac{x}{2} + \frac{x}{3} = \frac{x}{4} + 7$$
Reducing to com. denom. $\frac{12x}{24} + \frac{8x}{24} = \frac{6x}{24} + 7$
Mult. by 24 and transpose, $12x + 8x - 6x = 168$
Or, $14x = 168$
Divide by 14, $x = 12$

If either side of the equation contain the square, cube, or any other root, both sides must be squared or cubed.

Thus in the equation:—

$$\sqrt{(10x + 3)} = 7$$
Squaring, $10x + 3 = 49$
Transposing, $10x = 49 - 3 = 46$
$$x = \frac{46}{10} = 4\tfrac{3}{5}$$

Those who wish to become thoroughly acquainted with this science, should consult Hutton's Mathematics, or any other work on the subject.

IV.—GEOMETRY.

For convenience of reference, we insert a few practical rules of Geometry, which may be found useful.

To find the areas of figures.

Circles. Multiply half the diameter by half the circumference.

Or square the diameter, and multiply that square by the decimal .7854.

Squares, or parallel sided figures. Multiply the base by the perpendicular height.

Triangles. Multiply half the base by the perpendicular height. If it have no right angle, draw a line from one angle perpendicular to the opposite side, and find the area of the two triangles separately.

Unequal sided figures of more than 4 *sides.* Divide it into any number of triangles, and find the area of each separately.

Regular Polygons. Inscribe a circle; then, multiply *half* the number of sides by the length of one side, and the product by the radius of the inscribed circle.

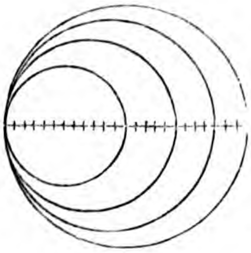
Cycloids. Take three times the area of the generating circle.

Parabolas. Multiply two-thirds of the base by the height.

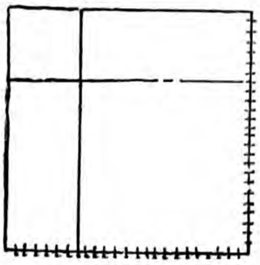
For long irregular figures, take the breadth at several equidistant places, add them together, except the first and last, of which only the half must be taken, and multiply by the distance between.

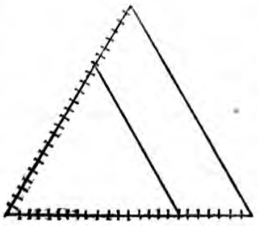
Obs. This is the rule used in calculating the area of water-lines for displacement; and the two preceding will also be found useful in certain cases in the same operation.

To construct figures of half or double the area of given similar figures.

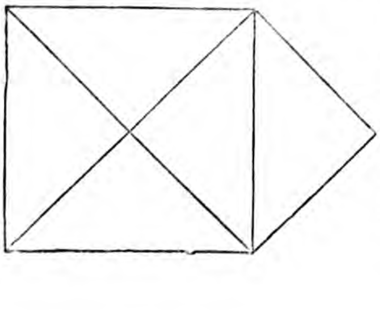


Circles. Divide the diameter into 24 equal parts, and take 12 for a circle of one-fourth the area, 17 for one-half, and 21 for three-fourths.

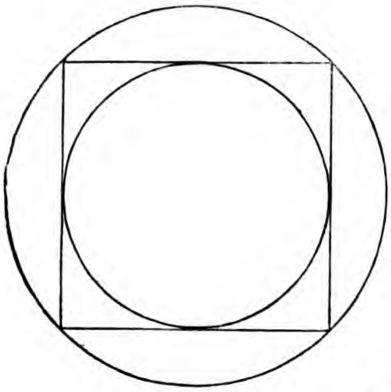




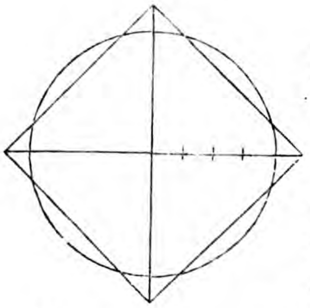
For a square, triangle, or other regular figure, take 17 parts out of 24 on two adjacent sides. If the figure be irregular, take 17 parts out of 24 on each side, and draw lines across.



A square may also be halved, by dividing it into four triangles, and doubling one of them, as here shown.



The circle embracing a square is double that inscribed in it, as in the annexed figure.



To form a square equal to a given circle. Draw two diameters at right angles, and divide the radius into 4 parts; set off one of these parts at each extremity, and through these points draw the square.

To erect a perpendicular to any line: construct a triangle whose sides are respectively as 6, 8, and 10. See Plate I.

The following table of the areas of circles will be found useful in calculating the contents or weight of round iron, spars, &c.:—

Dia.	Area.	Dia.	Area.	Dia.	Area.	Dia.	Area.	Dia.	Area.	Dia.	Area.
	.785	3	7.068	5	19.635	7	38.484	9	63.617	11	95.033
1¼	1.247	3¼	8.295	5¼	21.647	7¼	41.282	9¼	67.200	11¼	99.402
1½	1.767	3½	9.621	5½	23.758	7½	44.178	9½	70.882	11½	103. 86
1¾	2.405	3¾	11.044	5¾	25.967	7¾	47.173	9¾	74.662	11¾	108. 43
1	3.141	4	12.566	6	28.274	8	50.265	10	78.540	12	113. 09
2¼	3.976	4¼	14.186	6¼	30.679	8¼	53.456	10¼	82.516		
2½	4.908	4½	15.904	6½	33.183	8½	56.745	10½	86.590		
2¾	5.939	4¾	17.720	6¾	35.784	8¾	60.132	10¾	90.762		

The circumference of a circle is about $3\frac{1}{7}$ times the diameter.

V.—ON INCLINED PLANES.

The inclined plane is the most simple of the mechanical powers, and a knowledge of its laws is important, in reference to the laying of ways for launching, and still more so to the construction of the railway heaving-up slips, now in such general use for effecting repairs, particularly of steam ships.*

The power or advantage of the inclined plane is as the proportion of the height to the base. Thus, on a plane sloping one in twenty, one pound over a pulley would draw up twenty, supposing that it moved without inertia or friction, and, consequently, that the smallest possible power would move it on a level. But as this can never be the case in practice, we must find the inclination at which the body will just overcome its own friction and inertia, and run down: the height of this plane will be to its base, as the power necessary to draw the body on a level is to its whole weight. To ascertain the weight that will draw it up the incline, we must apply the rule given above, viz., as the base is to the height, so is the weight to the power, and *add* the weight that has been found necessary to draw it on a level. Hence it requires twice as much power to draw a weight up the incline on

---

* These slips have been extensively fitted by the author in Holland, Spain, the Danube, and many ports in England.

which it will just run down of itself, as to draw it on a level. For example, if a ship weighing 100 tons will just run down an incline of one in twenty, then it would require 1-20th of 100, or five tons to draw her on a level, and ten tons to draw her up that incline. Again, if it were required to know what power would draw the same ship up an incline of one in ten, then we have 1-10th of 100, or 10 plus the weight required to draw her on a level, or 5 tons=15 tons.

It is found that a ship, under ordinary circumstances, will run down an incline of somewhat less than 1 in 20; the railway slips are therefore laid at about this declivity.

In reference to the velocity of bodies moving down inclined planes, it is to be observed, that a body falling through the air freely descends about 16 feet in the first second, 32 in the next, &c., and that the velocity on an inclined plane will be diminished in the proportion of the height to the base. Thus, a body on a plane descending 1 foot in 16, would fall only one foot on the first second, without friction; and if we subtract from the given declivity that which is required to start the body, then as the length is to the remainder, so is 16 to the actual velocity in the first second, doubling for each successive second.

VI.—WEIGHT OF SHIPS.

The following extracts from the valuable work of Edye will materially assist the calculation of displacement:—

Class.	Tons' Measurement.	Weight. Hull only.	Weight at Sea.
		Tons.	
Cutter	160	83	160
10 Guns	235	157	283
18 „	382	214	456
28 „	500	414	784
46 „	1063	795	1466
52 „	1468	1042	2110
74 „	1741	1617	2976

WEIGHTS OF GREEN AND SEASONED TIMBER, PER CUBIC FOOT.

Name of Timber.	Green.		Seasoned.	
	Lbs.	Oz.	Lbs.	Oz.
English Oak	71	10	43	8
Dantzic do.	49	14	36	0
African Teak	63	12	60	10
Indian do. { Malabar do.*	...	...	52	15
Indian do. { Rangoon	...	...	26	4
Indian Mast Peon	48	3	36	0
Cedar	32	0	28	4
Larch	45	0	34	4
Riga Fir	48	12	35	8
New England do.	44	12	30	11
Elm	66	8	37	5
Beech	60	0	53	6
Ash	58	3	50	0

The average weight of timber for the hull may be taken at 50 lbs. to the cubic foot; and for the decks, masts, and spars, at 40 lbs.

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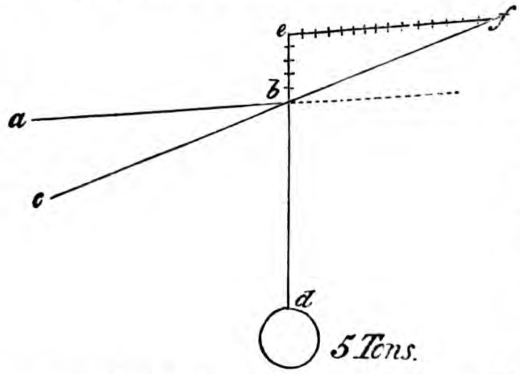
* The weight of Indian Teak, green or seasoned, is about the same.

VII.—ON SHEERS AND GUYS.

To ascertain the strain upon the guys of sheers, at any given inclination.



Let *a b* represent the guy, and *c b* the sheers: produce both lines; take any part *e b* and divide it into as many parts as there are tons suspended at *d*: draw *e f* parallel to *a b*, and divide *e f* into parts equal to those into which *b e* was divided: the number of these parts will be the number of tons strain on the guy. Few persons are aware of the great strain upon a guy, when it approaches a horizontal position. It will be seen that in the annexed diagram, a weight of five tons only suspended from *b*, will produce a strain of 15 tons upon the guy *a b*. Many fatal accidents have arisen from inattention to this fact.

VIII.—ON THE USE OF MOULDS, &c. IN DRAWING PLANS FOR SHIPS.

In designing or drawing a draft, moulds of various mathematical figures will be found very useful: particularly segments of circles, of from 10 to

40 feet in diameter, for the sheer lines, &c Parabolas, whose distances between the points of construction are from a quarter of an inch to 6 inches, will also be of great service. The parabola is capable of easy mathematical construction, and as a complete line can be variously applied in ship drafting, as seen in the construction of the midship section and half breadth.

The *Cycloid*, or curve described by any point in the circumference of a circle while making a complete revolution along a straight line, is the curve which offers least resistance to a fluid through which it is propelled; and is well adapted for drawing the various lines of a ship's body. It is not, however, like the parabola, subject to any fixed law, and cannot be mathematically described, except by rolling a circle along a straight line.

The following are the usual sizes of Drawing Paper:—

	Inches.		Inches.		Inches.		Inches.
Antiquarian	53	by	41	Imperial	30	by	22
Double Elephant	40	,,	27	Super Royal	27¼	,,	19¼
Atlas	34	,,	26	Royal	24	,,	19¼
Colombier	35	,,	23½	Medium	22¾	,,	17½
Elephant	28	,,	23	Demy	20	,,	15

IX.—ON FITTING SHIPS.

The injudicious practice of fitting ships for sea in merchant yards having obtained so generally, the following data are given as the results of extensive calculation:—

Cost of fitting merchant ships, to one ton of register tonnage.

Copper when at 1s. per lb.	12s. per ton.
Iron work (when copper fastened), including mast and spars	17s. do.
Blocks	4s. do.
Rope	50 lbs. weight.
Sails	10 yards.
Chains and anchors	10s.
Copper Sheathing	20s.

THE END.

ERRATA.

Page 40, line 6, for " to its proper place in the body plan," read, " in the half breadth plan."

Page 70, line 4, for " entire depth," read " entire weight."