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VXH

CRISP

A Treatise

ON

MARINE ARCHITECTURE,

Sec. Sec. Sec.

A Treatise
ON
MARINE ARCHITECTURE,

ELUCIDATING

The Theory of the Resistance of Water ;

ILLUSTRATING

THE FORM, OR MODEL, BEST CALCULATED TO UNITE VELOCITY, BUOYANCY, STABILITY, AND STRENGTH IN THE SAME VESSEL ;

AND FINALLY

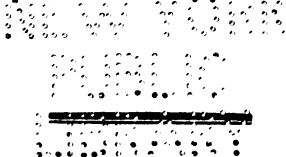
ADDUCING THE THEORY OF THE ART OF SHIP-BUILDING.



BY

CAPTAIN M. F. CRISP,

Of the Country Service.

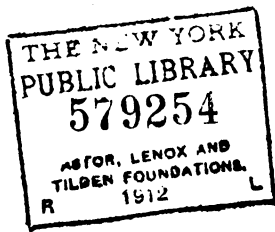


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CORRIGENDA.

- P. 4. l. 17. *for* "Panlany," *read* "Panlang."
26. l. 15. *for* "de Baut," *read* "de Buat."
36. l. 16. *for* "other," *read* "their."
44. l. ult. *for* "evidenced," *read* "evinced."
48. l. 5. *for* "steer," *read* "other."
51. l. 13. *after* "this," *insert* "accident."

PREFACE.

LEAVING to others the office of tracing the origin and progressive advancement of Marine Architecture, sufficient remains to be done to describe the properties which vessels must necessarily possess to be perfect sea boats; to elucidate and explain the manner of obtaining these properties; and, finally, to unite them in the same vessel, that each may be predominant without deteriorating from the others.

Of the many writers who have written on Marine Architecture, no two of them have agreed in proportioning the breadth to the length, or the depth to either breadth or length—or in placing the extreme breadth, the centre of gravity, of displacement, and

of lateral resistance or rotatory motion,—the position of the masts,—nor on the form best adapted to produce velocity, buoyancy, or natural stability; much less on the model or form best adapted to unite the above properties or qualities in the same vessel, which is proved by the variation in every succeeding vessel built. Their nearest agreement has been to determine, that the “breadth should be one third or one fourth the length, and that the extreme breadth ought to be before the midships of the ship.”

The obscurity in which the true principles of Marine Architecture continue to be involved, may be attributed,

1st. To the disinclination of builders to communicate freely with experienced seamen. And,

2dly. To the mode of admeasuring vessels to obtain their register tonnage, whereby ship-owners and ship-builders are interested in constructing ships after one form

or model, namely, that form which enables the vessel to carry one third to one half more cargo than its register tonnage; with the view to evade that proportion of the tonnage, and light and harbour dues, and to sail their vessels with a proportionable smaller crew. While, therefore, improvements are obstructed by professional prejudices or interested motives, or theories consulted that are founded on erroneous or narrow principles, it will be next to impossible to extricate the rudiments of this noble science from their present obscurity.

To have a just idea of the theory of Marine Architecture, the mind must be divested of professional prejudices; the laws and the causes of resistance of water must be carefully investigated; and in fact we must

“ E’en follow nature, of each art the soul :

“ Parts answering parts, shall glide into a whole,

“ Spontaneous beauties all around advance,

“ Start e’en from difficulty, strike from chance,” &c. &c.

A fish, for example, conveys a good idea of the form of a vessel intended for velocity; but it gives no idea of that of stability or buoyancy, qualities that are indispensable for the safety of a vessel.

On the other hand, the form of the albatross, the duck, and other water fowls, gives a good idea of the form best adapted for buoyancy, but no idea of that of velocity.

As, however, a vessel is not required to have the same degree of velocity as the fish, the practicability may be conceived of reconciling in some degree the form of the albatross to that of the fish, and thereby unite in the same vessel the two most essential qualities, namely, velocity and buoyancy.

A vessel calculated to keep on an enemy's coast with all winds, or to work off a lee shore, must have good hold of the water, and therefore be deep in the water to hold a good wind; whereas a vessel intended to navigate in shallow water, or to take the ground,

must have a flat and a long floor, and therefore be shallow, in order to draw the least water, and to avoid straining when she lies on the ground.

Nature formed flat fish to lie securely on the bottom, and to inhabit rivers and shallow water; whereas the dolphin and other fleet fish that inhabit the sea, are formed deep, doubtless to add to their velocity.

The perseverance with which writers on ~~Marine~~ Architecture have endeavoured to give the same properties to vessels that are intended for different purposes, has much impeded the advancement of the art; and when to this be added the notorious prejudice and adherence of ship-builders to old habits and customs, we need not be surprized to find them governed in the form or model of the vessel to be built, either by precedent, caprice, or convenience, and that this noble art has not advanced one step beyond practice.

Chapman, in his celebrated work on Marine Architecture, translated in 1820, by Professor Inman, is constrained to confess :
 “ The construction of a ship with more or
 “ less good qualities, is a matter of chance,
 “ not of previous design : and it hence fol-
 “ lows, that so long as we are without a good
 “ theory on ship-building, and have nothing
 “ to trust to beyond bare experiments and
 “ trials, this art cannot be expected to ac-
 “ quire any greater perfection, than it pos-
 “ sesses at present.

See Professor 1

“ It becomes a matter of importance, then,
 “ to discover what may bring this know-
 “ ledge to greater perfection. Seeing that
 “ ships, the proportions of which lie within
 “ the same limits, nay, which have the same
 “ form, differ greatly from each other in re-
 “ spect to their qualities, and even that with
 “ a small alteration in the form, a ship ac-
 “ quires a quality immediately opposite to
 “ the one we wish to give it, we must con-
 “ clude this arises from certain physical

“ causes; and that the art of constructing
“ ships cannot be carried to greater perfec-
“ tion, till a theory has been discovered
“ which elucidates these causes.”

It must be manifest to every amateur, nay, even to the most superficial observer on Marine Architecture, that while the theory of resistance of water (the foundation of Marine Architecture) remained unknown, the Theory of Marine Architecture would remain undiscovered, neither could the art be much improved by the writings of our ablest mathematicians. Hence Euler's elaborate work on the construction and properties of vessels failed to afford the improvements in the art, which the author and translator evidently contemplated. In page 93 and 94 of that work, is the following remark relative to resistance:--
“ But as the theory of resistance which we
“ have hitherto considered, must be allowed
“ to be very defective, and that we cannot
“ entirely depend upon the conclusions

“ which are drawn therefrom, we may well
“ spare ourselves the trouble of such diffi-
“ cult researches. For although we have
“ already supposed that the simple pres-
“ sures which the body of a vessel sustains
“ when in motion, do mutually destroy each
“ other, yet we are certain this can only
“ happen when the vessel is at rest, since
“ the water behind the vessel must follow
“ and overtake it before any pressure can
“ be exerted : it is therefore evident, that
“ the pressure upon the aft part cannot be
“ so great when the vessel is in motion, as
“ when it is at rest ; whilst the pressure up-
“ on the fore part will nearly be the same
“ in both cases. From whence it follows,
“ since the pressure upon the fore part is
“ no longer counterbalanced by that upon
“ the aft part, the effect of this resistance
“ must necessarily be increased ; and this
“ increase will by this means be so much
“ the more considerable, as the velocity of
“ the vessel becomes greater : and however

“ little consideration we may employ upon
 “ this matter, we may easily conceive that
 “ this increase must depend principally
 “ upon the figure of the aft part of the ves-
 “ sel, which we have hitherto entirely ne-
 “ glected. On this account it appears very
 “ probable, that notwithstanding all our en-
 “ deavours to determine the exact resist-
 “ ance, we may perhaps still vary consi-
 “ derably from the truth.” And in a more
 recent work on resistance, (Robison’s Me-
 chanical Philosophy,) the author concludes
 by observing:—“ Thus have we attempted
 “ to give our readers some account of one
 “ of the most interesting problems in the
 “ whole of mechanical philosophy. We
 “ are sorry that so little advantage can be
 “ derived from the united efforts of the first
 “ mathematicians of Europe, and that there
 “ is so little hope of greatly improving our
 “ scientific knowledge of the subject. What
 “ we have written will, however, enable our
 “ readers to peruse the writings of those who

“ have applied the theories to practical purposes. Such, for instance, are the treatises of John Bernoulli, of Bouger, and of Euler, on the construction and working of ships.”

My object in adverting to these remarks on resistance, is with the view to unbias the reader's mind, and at the same time to give him some idea of the obscurity and difficulty of the subject.

After twenty years experience and close observation on the properties of various vessels, under every circumstance, at sea, I became convinced of the causes which more or less affected their good or bad qualities. This conviction impelled me to investigate and comprehend the laws of fluids ; and this again led to the important discovery of the predominant cause of resistance, which retards the velocity of all bodies when they are passed quickly through the water.

The following Treatise commences with a concise account of the laws and resistance of fluids, which the avocation of a seaman but little qualifies him to elucidate in a pleasing or agreeable style. It then proceeds to elucidate and explain the causes that produce, or which more or less affect the good qualities in a vessel,—reconciles those causes on theoretic principles,—and finally demonstrates the principles of the art of constructing vessels, in so plain a manner as to render the subject easy of comprehension to every reader.

From the various kinds and various forms of vessels that navigate the Indian seas, and from the cordial interchange of liberal opinions and sentiments between gentlemen of different professions, more especially those of ship-building and seamanship, there is no part of the world better qualified to appreciate the observations and remarks contained in the following sheets than India. If, therefore, this effort to improve the art of

ship-building should evince error in judgment, the Author has the consolation to know, it cannot be impeached by the choice made of the tribunal to try the merit of his performance.

CHAPTER I.

Of the Laws of Fluids, particularly Water.



1st. “**WATER** presses with equal force
“ in every direction,” and its degree of
pressure is in proportion to the distance
from its surface.

The great Dr. Halley says, “ That the
“ pressure of the water at thirty-three feet,
“ pressed the natural air into half its space
“ in his diving-bell;” and by many experi-
ments made by Captain Hutchinson, it ap-
pears, that “ the pressure of water upon
“ bottles of different shapes, corked up with
“ nothing in them but common air, was as
“ follows :—Two common square flat-sided
“ bottles, which would hold three half pints
“ each, broke at the depth of between six
“ and seven fathoms ; but two oval formed

“ Florence flasks, of nearly the same size,
 “ bore the pressure to about fifteen fathoms.
 “ A round common quart bottle broke only
 “ at about twenty-eight fathoms. It seems,
 “ at a great depth, few things that are made
 “ hollow and tight, will bear the water’s pres-
 “ sure: an instance of which has been seen
 “ by a ship that drove off the bank in Gibralt-
 “ ar Bay, into water so deep, that the an-
 “ chor would not reach the ground at a hun-
 “ dred fathoms; and when hove up, it was
 “ found that two new nun-buoys had their
 “ sides crushed inwards by the water’s pres-
 “ sure.”

2dly. “ All floating bodies displace as
 much water as is equal to their weight,” and
 are subject to the same laws as the quantity
 of water would have been which such bodies
 have displaced.

Fill any vessel with water, and place it in
 a scale with an equal weight in the opposite
 scale, then place any floating body in the
 water, and it will be seen to displace a quan-
 tity of water equal to its weight.

Place models of different shapes (from
 the wedge to the wedge reversed) in a line
 abreast of each other, in a stream that runs

to a waterfall, and they will be seen not only to descend with the stream, and form every curvature with the eddy water, but they will be seen to fall in rotation, according to the fulness of the advanced end or bow, and this because of the greater quantity of water displaced by the advanced end.

3rdly. Water runs to its level, or into a vacuum, at a determined velocity, according to the pressure of the surrounding fluid.

All fluids possess a natural velocity, according to their density or cohesion. This will be seen, by pouring several fluids of different densities down an inclined plane at the same instant; suppose tar, oil, molasses, water, &c. when the fluid which possesses the greatest degree of cohesion, adhesion, or attraction, will be seen to run with the least velocity. The adhesive power of water is evident, by the quantity that may be dropped into a glass, after the water is level with the rim of the glass; and again, by the number of small particles of rain that compose a large drop, before the latter descends from any intercepting body: on this principle the phenomenon is accounted for, of the water being several inches

above the (quarter) gunwale of a boat, when towed quickly through the water by a whale, &c.

Drop a piece of solid metal into a quantity of metal in a state of fusion, or into any fluid, and it will be seen that the vacuum thus created will require a greater or lesser time to fill, according to the density or adhesion of such fluid.

The natural flow of water is seen in every aqueduct, and is farther evinced by alternately raising the end of a tube or trough containing water. This natural flow is manifest in every river:—at the mouth of Rangoon river, where the tide rises upwards of 20 feet, it is there high water at 3 o'clock; while at Panlany, about 80 miles up the river, it is then low water, and *vice versa*. The mean velocity of the tide in this river during the year, may be estimated at three to four miles per hour; and by taking this river as a criterion, we may estimate the natural flow of water at three to four miles per hour.

4thly. The vacuum made by a body passing quickly through a fluid, is in proportion to the density of the fluid, to the velocity

with which it is passed through it, and to the fulness or squareness of the hindermost end of such body.

Move a wedge, for example, through tar or oil, with the small end foremost, at the rate of three miles an hour, or three and half feet per second, and there will be seen a large vacuum behind : reverse the wedge, and move it with its large end foremost, at the same rate, when little or no vacuum will be seen. A vacuum is seen behind a ship's rudder, when sailing fast ; also behind a boat's oar, in the act of being pulled strong. In fact, a vacuum is made by passing your hand flatways through water, or a teaspoon through a cup of tea, but much more so through a more dense fluid.

5thly. All bodies specifically heavier than water, descend to a point where the upward pressure of the water is equal to their weight.

This is demonstrated in the act of sounding in deep water, when the person that holds the line supposes the lead to be at the bottom, when no bottom is to be found : again, by the decreasing rate at which the deep sea lead descends ; and may be seen

by the distance which pieces of wax, made specifically heavier than water, will be suspended from the surface of a glass of water.



CHAPTER II.

Of the Resistance of Fluids.

“ THE theory of resistance is a subject
“ which has exercised the extraordinary
“ talents of the most distinguished mathe-
“ maticians of the last century. Neverthe-
“ less it is a subject which is as yet very
“ imperfectly known. It seems that Sir
“ Isaac Newton was the first who attempted
“ to make the motion and actions of fluids
“ the subject of mathematical discussion ;
“ yet even he, with all his genius and all his
“ science, was at length convinced that it
“ was in vain to expect an accurate investi-
“ gation of the motions and actions of fluids,
“ where millions of unseen particles com-
“ bine their influence; &c. He however
“ figured in his mind an hypothetical

“ theory; and from this hypothesis deduced
 “ a series of propositions, which formed the
 “ basis of all the theories of the impulse
 “ and resistance of fluids that have been
 “ offered to the public since his time.

“ From these theories the following prin-
 “ ciples were deduced, as the laws of the
 “ resistance of fluids : we give them here,
 “ in order to shew how far they have been
 “ found to agree with actual experiments,
 “ in what respects they differ, and to pre-
 “ vent the young artist from retaining those
 “ erroneous ideas of the subject which he
 “ perhaps may have already acquired.”

1st. “ The resistance, and (by the laws of
 “ motion) the impulsions, of fluids on simi-
 “ lar bodies are proportional to the surfaces
 “ of the solid bodies to the densities of the
 “ fluids and to the square of the velocities
 “ jointly.

2dly. “ The direct impulse of a fluid on
 “ a plain surface is to its oblique impulse,
 “ as the square of the radius is to the square
 “ of the sine of the angle of incidence.”

3dly. “ The direct impulse on any surface
 “ is to the oblique impulse on the same sur-
 “ face, as the cube of radius to the solid

“ which has for its base the square of the
 “ angle of incidence, and the sine of obli-
 “ quity for its height.

4thly. “ The direct impulse of a fluid
 “ whose breadth is given, is to its oblique
 “ effective impulse in the direction of the
 “ stream, as the square of radius to the
 “ square of the sine of the angle of inci-
 “ dence.”

“ The numerous experiments with which
 “ these propositions have been compared,
 “ have most decidedly proved that they are,
 “ with the exception of the first, exceedingly
 “ erroneous; and even that is not in all
 “ cases correct*.”

The translator of Chapman’s celebrated
 work on Marine Architecture there states:—

“ That Chapman’s theory of resistance to
 “ ships cannot be depended on, as leading
 “ to true results, in as much as he admits
 “ into it two suppositions which have been
 “ repeatedly proved by experiments to be
 “ false.

“ In his interesting experiments printed
 “ at Stockholm in 1795, he endeavours to
 “ substitute another theory in the place of

* Steel’s Marine Architecture.

“ the one given in his Marine Architecture.”

“ It is to experiment, and perhaps to experiment alone, that we are to look for the basis of a true theory of resistance and impulsion.”

Water being the foundation and life, as it were, of marine architecture, it is hence manifest, without a true theory of the resistance of water, the true theory of marine architecture can never be discovered.

The resistance of fluids is in proportion to their density, cohesion, adhesion, or attraction.

The opposition which any body meets in its passage through water arises,—

1st. From the cohesion or *vis inertiae* of the water.

2dly. From the adherence of the water to such body, or the friction; and,

3dly. From the retractive power of the vacuum created by a body passing quickly through the water.

The natural flow of water being taken at three to four miles per hour, at the same time bearing in mind that water flows into a vacuum from every direction, it is therefore

obvious that when bodies are moved slowly through the water, say six miles per hour, the water is enabled to keep in contact with the hindermost end of such bodies by virtue of its natural flow, in which case there is no vacuum: consequently such bodies are resisted by the “*vis inertiae*” and the friction of the water only.

Upon this principle the phenomenon is explained, which is witnessed in every large fleet, namely, that full-built ships frequently outsail our finest ships in light winds and smooth water.

Owing to the experiments of M. De Romme not being made with sufficient velocity, he “found that bodies advanced with the same celerity when drawn by the head end, as when drawn by the stern end; of course that it was indifferent which end moved foremost.”

Even the square formed sailing barges in London river will in a fresh breeze and smooth water exceed six miles an hour, whereas our finest sailing ships will rarely exceed four miles in a seaway sailing close to the wind.

It is an undisputed fact, that a loose rickety vessel will sail much faster than when she was immoveably bound.

Hence it follows, to ascertain with precision the laws of resistance, so as to discover the comparative advantages arising from the form, either of the head end, or of the midship body, or of the stern end of all kinds of navigable vessels by means of models, the experiments must be made in agitated water, and to be drawn through the water at the rate at which fast sailing vessels can sail, namely, 10 to 15 miles per hour, or 20 to 25 feet per second. From these points being neglected by the Society for the Improvement of Marine Architecture, and other experimentalists, their experiments failed in determining the form of a vessel best adapted for velocity.

Consequently seamen are now the only experimentalists to whom we are to look for true results respecting the laws of resistance of water.

The nature of *vis inertiae*, and the power requisite to overcome it, together with that of friction, having been so elaborately explained by the Society for the Improvement

of Marine Architecture, very little remains to be said.

It may be proper, however, to remark, that the effect of friction diminishes when vessels obtain their greatest speed, which is proved by the rate at which wood bottom vessels sail in a fresh breeze.

In 1811, I commanded a Swedish built brig out of London, called the Louisa, not coppered, that sailed $9\frac{1}{2}$ to $10\frac{1}{2}$ miles per hour for several hours.

Every person that has walked in the water up to their waist, must be convinced of the remarkable fact, namely, that when they attempted to increase their speed through the water, then the resistance of the water increased in a double ratio.

The power of the water is incalculable.

“ Place a ship in a dock, that is made to fit
 “ the exact shape of her bottom, leaving
 “ only the smallest space between the ship
 “ and the dock; fill that space with water,
 “ and the ship will be as effectually floated
 “ as if she was in the ocean.”

The smallest vacuum between a vessel and the water will attract such vessel equally strong with the largest vacuum. Remove

the water from one side of the dock, and the vessel will be as strongly attracted as if the whole side of the dock had been removed by magic.

Water presses equally in every direction: if, therefore, the smallest vacuum were made in the water at any particular part of a vessel floating, the full force of a column of fluid would be immediately felt in a contrary direction, forcing the vessel into such vacuum.

A vacuum is seen on the opposite side of an erect post, in a stream of water against which the stream is running with great velocity: it is likewise seen behind any square body moved quickly through the water; behind a vessel's rudder, when sailing fast; by passing a spoon quickly through a cup of tea, or your hand flatways through the water.

The retractive power of a vacuum is evinced by the vibration of the rudder, and even the vibration of the after body of every vessel, when sailing at their utmost speed. It is confirmed by the practice of unloosening privateers, &c. to increase their velocity when closely pursued by an enemy;

which is effected by rendering the vessel pliable, for when pliable she yields to the retraction of the vacuum under either quarter, and consequently is less forcibly retracted by the vacuum. This fact, however, is known to every person accustomed to boat sailing. I well remember having charge of a boat in the river Plate, which when loose and rickety, and so leaky as to require a man continually to bale her, then outsailed every boat ; but after she was firmly bound, then every boat beat her.

The power of the vacuum is demonstrated by a spar or long piece of wood being plunged into the water in an oblique direction, when, notwithstanding the greater degree of upward pressure of the water on the lowest end of the spar to alter its line of direction, (which, admitting the spar to be 16 feet long, would be four times more effected by upward pressure of the water than the uppermost end,) yet the spar, or a boat-hook staff, will be seen to return in the precise direction in which it entered the water.

The power of the vacuum is again proved in the act of pumping quickly. The piston being raised faster than the water flows, or

can follow the piston, a void or vacuum is created between the piston and the water, at which time the piston is forcibly retracted by the vacuum, until the water comes again in contact with the piston, when the pump makes a hollow sound, termed striking by seamen.

The retractive power of the vacuum retards descending bodies from reaching the bottom quickly. A deep sea lead, for example, dropped from the forecastle of a ship 120 feet long, and she sailing at the rate of eight miles per hour, would not reach the bottom in 20 fathoms water, by the time the stern of the ship arrived at the spot where the lead entered the water: on this account pilots are obliged to reduce the rate of a vessel's sailing, when correct soundings are required in 20 fathoms.

Every person that has hauled in the log-ship with its pin in, and the ship sailing fast, must be convinced that it requires much greater power than would be requisite to haul in a fish of twice the thwartship size of the log-ship.

A floating anchor derives its power to hold a vessel from the retractive power of

its vacuum. Upon the same principle, the droge of one foot square used by whalers to impede the velocity of whales, more effectually retards the whale than three boats, although the thwartship section of each boat with her crew and equipment must have two square feet immersed in the water. Again, when a dead whale is to be towed to the ship, it is towed with its head foremost; but when it is required to act as a floating anchor to a vessel, then the cable is fastened to the tail of the whale.

For the same reason, a vessel with a fine lean bow acquires much greater velocity in her stern boards than a vessel with a full bow.

The following experiments, however, will more effectually demonstrate the retractive power of the vacuum.

Have models of every kind of navigable vessels; let them be made hollow, having holes pierced through them in every part, and of the same specific gravity: place them with their stern ends in a line with each other in a stream of water, just above a waterfall, or near any vacuum in the water, and on their near approach to the waterfall

or vacuum, it will be seen that those models which have the fullest runs, or in other words, which have their centre of displacement nearest the stern end, will not only emit the greatest quantity of water through the holes in the stern, and quarters, but will be the first precipitated or attracted into the vacuum ; while those models whose centres of displacement were farthest from the vacuum, or nearest the head, will be the least attracted, and consequently the last precipitated down the waterfall.

If, then, equal weight had been fastened to the models, it is evident, that when their stern ends were at the brink of the waterfall, the weight which would be able to sustain from falling those models whose centres of displacement were farthest removed from the vacuum, would be inadequate to sustain those from falling whose centres of displacement were nearest the vacuum, and which were the first precipitated down the waterfall. And as it requires the same power to sustain any body immoveable in a stream of water, as to propel it through stagnant water at the rate at which the stream was running, it follows hence, that a vessel,

whose centre of displacement (every thing else being the same) is the farthest removed from the stern, will obtain the greatest velocity with the propelling power ; that is, the vessel with the longest run (every thing else being the same) will sail the fastest.



CHAPTER III.

Observations, &c. on the Causes which produce, or which more or less affect, the primary Properties of Navigable Vessels.



A navigable vessel, to be a safe and perfect sea boat, must have velocity, buoyancy, stability, and sufficient strength to withstand the shock of wind and waves.

These primary properties embrace steering well while scudding, lying too with safety, sailing fast by the wind, holding a good wind, staying and wearing promptly, riding easy at anchor, pitching and rolling easy, capacity, &c. &c.

Therefore, in the construction of a vessel intended to cross the sea, the first and primary consideration should be regarding her safety, and not respecting her capacity; or,

“ That a ship with a certain draught of water, should be able to contain and carry a determinate lading. ” Thus encouraged to render a vessel capacious and burthensome by the most celebrated writer on marine architecture, it would be indeed extraordinary were ship-owners or ship-builders to sacrifice their interest in the construction of a vessel for her safety, when almost every vessel can be insured ; and if lost, why, no loss to them. Not so, however, to the country to which such ship belongs. I conceive the safety of the crew to be of so much importance to a state, as to claim the attention of governments to the safety of all navigable vessels.

Overbuilt, capacious, burthensome vessels, are in the greatest repute with British ship-owners, which necessarily must influence ship-builders to build their vessels of that description and form ; and vessels of this construction require extraordinary large rudders to steer them, even in a tide’s way.

Of the many vessels lost from being unsafe at sea, few or none of the crew survive to give the melancholy account of the cause of their disaster.

In a cross turbulent sea, there is nothing more dangerous than a large rudder. I am convinced there are more vessels lost from having large rudders than from every other cause. This must appear evident to every person, when the square stern and after body of a ship is duly considered.

First, the after body is unsupported by the water.

Secondly, the after part of the after body is composed of fashion pieces and dead wood.

And thirdly, the stern frame is erected on a transom, which transom is again supported by the stern post.

Being thus constructed, it would be miraculous if the stern, the stern post and after body, should sustain the shock of the sea against the rudder in a heavy gale uninjured or unshaken, when it frequently happens that two men at the wheel are found inadequate to sustain the shock of the sea against the rudder in a calm.

In October 1822, I commanded the ship *Victory*, of 700 tons : we experienced a very heavy gale in the Bay of Bengal ; our tiller broke at the commencement of the gale.

The force of the gale kept the ship on her beam ends. The lee sea not only washed our longboat some feet forward, and the wedges out of the foremast, but the water went down the rudder case from the poop cabins. In the end, we had to cut away our main and mizen mast to prevent the ship from foundering.



Remarks, &c. on the Form of a Vessel best adapted for Velocity.

It was demonstrated in the preceding chapter, that a vessel whose centre of displacement was farthest removed from the stern (every thing else being the same) would, with the same propelling power, obtain the greatest velocity; that is, the vessel which has the longest run will sail the fastest.

Every vessel possesses a certain degree of velocity; and many of them can obtain their utmost speed in smooth water under their skysails. Many fine built ships sail equally fast under their jury masts, as when they are properly masted.

The rudder may be considered the index of velocity ; for in proportion as the eddy water or vacuum increases about the stern, the power of the rudder diminishes, until it ceases to have the power to steer the vessel, save within three or four points each way : hence arises the inability and the danger to scud in a strong gale, even when it is favourable.

The motion arising from pitching, is the principal impediment to velocity.

Because, 1st. By the run and after body being suddenly raised out of the water, a vacuum is created.

2dly. By pitching, a greater quantity of water opposes the advance of the vessel ; and,

3dly. By the pitch, 'scend, or lurch, the direction of the vessel's course is altered, while the effect of the wind on the sails is thereby diminished.

The principal cause of the extraordinary motion in vessels consists, —

1st. In the formation of their bottoms : witness the boats in the river Hooghly, particularly the bhur, paunceway, and dingey, which from being water borne in midships only, are set in motion by the least ripple

or agitation of the water, or by the least weight laid suddenly on either extreme. Whereas the Burmah canoes, from being water-borne forward and aft, will sustain a large gun on the bow, and not acquire one twentieth of the motion, in the same sea, which the dingey, paunceway, or bhur would have had ; and,

2dly. In the position of the centre of weight or gravity. Let two vessels, for example, of the same size and construction, be laden, one of them to have the centre of weight or gravity placed some distance abaft the midships, the other with the centre of weight the same distance before the midships; propel them at the same rate against a head sea, and it will be seen, that the one whose centre of gravity was farthest forward opposes the greatest resistance to the upward pressure of the head sea, and therefore is less moved or lifted than the one whose centre of weight was farther aft.

Hence it follows, that vessels intended to have velocity should be formed,—

1st. With a long run.

E

2dly. Should be made water borne as much as possible, particularly the after body ; and,

3dly. Should have the centre of weight carried well forward.



Remarks on the Formation of the Bow.

The principal points to be attended to in the formation of the bow are,—

1st. To diverge and divide the opposing water with the least difficulty.

2dly. To assist the vessel to rise buoyantly over the sea ; and,

3dly. To prevent plunging into the sea.

The experiments of the Chevalier de Baut go far to shew, that the formation of the head of a vessel is of less importance in overcoming the *vis inertiae* of the water than it has been considered heretofore. He found, “ by an instrument consisting of a square
“ brass plate, pierced with a great number
“ of holes, and fixed in front of a shallow
“ box exposed to a stream of water, the
“ remarkable circumstance, that in great
“ velocities the holes at the very border,

“ and even to a small distance from it, not only sustained no pressure, but even gave out water.”

A long bow necessarily contracts the length of the floor, and length of the run, and by lengthening the overhang of the fore body, increases the disposition to pitch.

A very bluff, or upright bow, in its passage through the water, raises a mound of water or small sea before it, by which the resistance of the water is increased in the manner shewn by M. de Baut's experiments; for “ when the box with the brass plate in front of it was not wholly immersed, there was always a considerable accumulation of water against the front of the box, and a depression behind it.” Besides, a bow too full below meets with increased resistance, because the pressure of the water increases in a double ratio in proportion to the depth: on this principle, “ a leak 16 feet under water will admit sixteen times as much as a leak at the surface.” For the same reason, the lowest immersed half of the ship meets with considerably more resistance than the half near the surface.

A middling full bow, not only admits the fore body to be considerably water borne, but likewise allows the centre of weight being carried forward: then by the bow raking forward 20 to 30 degrees, at the same time to flare or flaunch out from the light water mark to the gunwale, the opposing water, by receiving the greatest divergency, would be divided with the least difficulty, while the rake of the bow would give it a tendency to rise over the sea, and the flare or flaunch out would prevent the bow from being plunged deeply into the sea. This form of a bow assimilates in a great degree to that of a grab; and the grabs (particularly the grab Nancy) are some of the fastest sailing vessels in India.

“ Captain Hutchinson, in the year 1746, was in a middling full built ship, called the Pearl, that was taken in light wind by a squadron of sharp Toulon built ships; but afterwards, when it came to blow so strong as to put us under close reefed topsails upon a wind, our vessel could be the headmost and weathermost ship of their fleet. I had afterwards,” says Capt. H. “ the command of a very extraordi-

“ nary sharp slight ship built at Malta,
“ with very small scantlings of timber and
“ plank, long, low, and narrow, being
“ only twenty-seven feet beam to eighty-
“ eight feet keel, with shelving, shallow,
“ sharp, main body, low buttocks for a
“ cruisingship, which purpose she answered
“ well in light winds, fine weather, and
“ smooth water. In chasing large, with
“ a little wind and a head swell, we have
“ steered right up to the chase, when
“ all their endeavours could not keep
“ their ship’s head to the swell, but lay
“ broadside to it. A small pressure of wind
“ and sail would put this shell of a ship to
“ her utmost speed ; so that we never de-
“ sired the wind to blow with a greater
“ velocity than about 10 miles an hour.”
“ But in tacking, when it blowed so fresh
“ that we could just carry whole topsails,
“ we were obliged to haul up our courses
“ to make her sure in staying, otherwise
“ she would get such sternway before she
“ brought the wind ahead, as prevented
“ her from staying. This ship was so weak,
“ that in bad weather, when the waves ran

‘ high, we could hardly keep her together ;
 “ and in chasing to windward at such times,
 “ she used to plunge her over sharp bow
 “ so deep into the waves, as to oblige us
 “ to shorten sail, and add bailing to pump-
 “ ing, to save her from sinking.”

By the bow being proportionably short, it admits of the floor and the run being proportionably long, qualities absolutely necessary to produce velocity. By a long floor, I mean a lengthened horizontal line of bearing about the floor heads.

The entrance of the bow should be similar to the life-boat built by Mr. Greathead, but not so fine. The stem to have about half the rake of the stem of a grab. The sweep for the bow at the load water line should be that recommended by Capt. Hutchinson, namely, half the three fourths of the main breadth. The upper sweep, or sweep of the gunwale, should be a semicircle from half the main breadth: then, by reconciling the load water sweep with the sweep of the gunwale with some concavity, it would give the necessary flare aloft. A bow formed as above, appears to me well adapted to divide the

opposing water, raise the vessel over the sea, and to prevent her from plunging deep into a head sea.

With regard to the form best adapted to go smoothly, little remains to be said, it being evident, that the vessel which possesses the greatest horizontal line of bearings, or being equally water borne forward and aft, will have the least motion, and therefore pass through the water with the greatest smoothness. Some attention, however, is necessary in the distribution of weight or cargo : care must be taken not to carry dead weight into either extreme, as neither of them are water borne. If the after body, for example, were cut off at the commencement of the run, it would swim several feet deeper than the main body. The same would happen, but in a less degree, with the fore body, were it cut off at the termination of the entrance, or by the fore channels.

Remarks, &c. on the Run.

In proportion as the after body is water borne, the tendency to 'send aft is diminished ; therefore the after body should be ren-

dered water borne as much as possible ; this is done by the run being formed of convex, instead of hollow water lines.

If it were not notorious, that length gives velocity, I would refer to the flying proa ; but more particularly to the inhabitants of Rangoon, who on being asked how many days a canoe will reach Ava from Rangoon, inform you, that if the canoe is four cubits broad, a month will be required ; if three cubits, then three weeks ; but if with less breadth, then 10 days. I scarcely need observe, these dimensions refer to canoes of the same length. Canoes, however, require but little stability, from their not using sails, particularly on a wind.

Since, therefore, that vessel which is most water borne, and having her centre of weight at the same time most forward, will acquire the least motion in a seaway, and since the vessel with the least motion and with the longest run will obtain the greatest velocity, being propelled in a seaway by the same power,

It is hence manifest, that without detriment to velocity, additional breadth may be given at the area of flotation, at the fore

body, when additional stability or buoyancy is required.



*Remarks &c. on the requisite Strength for
a good Sea Boat.*

Without reference to the preceding remarks, it is obvious, that every additional weight in a vessel, whether it arises from large or heavy scantling, extra fastenings, sleepers in the afterhold, &c. &c. is detrimental to buoyancy, to velocity, and to the general safety of the vessel.

Owing to the extraordinary fastenings which are absolutely necessary to connect and support the disproportionate parts of overbuilt burthensome vessels, and of rendering others sufficiently strong to take the ground, from long practice, ship-builders have acquired the habit of giving unnecessary strength and weight to the finer class vessels. To be convinced of this, we need only examine the many old crazy vessels that have encountered the heaviest gales, which, on being broken up, excite our astonishment that they had held so long

together; or to examine the many slender built privateers, smugglers, &c. that navigate in the worst seas, and weather with the greatest safety.

It is notorious, the Masoola boats on the coast of Coromandel owe their safety and their velocity to their buoyancy and pliability; while it is evident, that all vessels sail worse by being immoveably bound with extra fastenings, &c. &c.

In a seaway, the water frequently leaves the after body entirely; in which case the whole weight of the after body is supported by the main body: from this cause the butts between the main and after body invariably complain first.

The round stern introduced into the navy by Sir Robert Seppings, is an invaluable improvement in ship-building. In the first place, a ship being taken aback in a heavy sea, is in no danger of going down stern foremost, which square stern ships are very liable to. 2dly, The round stern facilitates convex water lines being given to the run instead of concave. 3dly, It dispenses with a great proportion of dead wood, fashion pieces, &c. 4thly, It admits of the whole

scantling being reduced about the stern ;
 And 5thly, Giving additional bearings and
 support to the after body. These are some
 of the advantages of a round stern.

A well formed vessel does not require
 half the size of scantling as the burthen-
 some overbuilt vessels require.

In 1823, I was in a well-formed native
 brig, in the Bay of Bengal, laden with
 4000 bags of rice, equal to 300 tons ; and her
 timbers and beams were only 5 by 4 and
 3 inches, and her planks were from 2 to 1½
 inches thick. We experienced a fresh
 breeze for several days, when I was de-
 lighted with her liveliness and buoyancy.

Long planks well fastened in the top
 sides, and in the upper deck, add consider-
 ably to the strength of a ship.



Observations, &c. on Buoyancy and Sta- bility.

An empty cask has buoyancy, but no
 stability : whereas a half round spar, posses-
 sing the same specific gravity as water, has
 stability but no buoyancy.

A ship made of fir is more buoyant than one made of oak ; and, every thing else being the same, the fir vessel will strain and labour much less in a gale than a vessel built of heavier wood.

The stability of a vessel consists, 1st. In her formation ; 2dly. The resistance of the water ; 3dly. The upward pressure of the water ; and lastly, The disposition of the weight or cargo on board the vessel.

Affix two bamboos to the keel of a boat, and their upward pressure will make the boat tender ; but affix them to the boat at the surface of the water, one on each side, as practised by the Burmahs to give stability to other canoes, and they will produce stiffness or stability.

“ On a reference to the case of three
 “ French seventy-fours, we shall be con-
 “ vinced how essentially the formation of a
 “ vessel contributes to her stability. The
 “ Scipio, Pluto, and Hercules, were found
 “ so crank as to render the lower deck
 “ guns deficient and dangerous. It was
 “ thought restowage would remedy the
 “ defects : the Scipio was unloaded, and
 “ again stowed, under the direction of the

“ chief engineer. In her first stowage, she
 “ had eighty-four tons of iron, and one
 “ hundred tons of stone ballast, and was
 “ reloaded with one hundred and twenty
 “ tons of stone ballast, and one hundred
 “ and ninety-eight tons of iron ballast; and
 “ as her draught of water, or displacement,
 “ could not be altered, it was necessary to
 “ diminish one hundred and thirty tons of
 “ water, in order to preserve the same load
 “ water line; by these means one hundred
 “ and thirty-six tons were placed in the se-
 “ cond loadening eight feet lower than in
 “ the first; yet when the ship was com-
 “ pleted with the new arrangement of stow-
 “ age, she was found precisely as deficient
 “ as before, inclining twenty-four inches
 “ with the men at quarter, and guns out on
 “ one side. She was afterwards doubled
 “ with light wood, to the thickness of a foot
 “ at the extreme breadth, and ten feet un-
 “ der water, decreasing to four inches
 “ length and depthways, which corrected
 “ the defect.”

The stability arising from the resistance
 of the water is proved in boats with sliding
 keels. Let down the keel when the boat

is under sail, and the inclination or heel over is considerably diminished, as well as the sudden roll prevented.

The upward pressure of the water is manifest on a vessel that has one side broader than the other. I well remember the mortification I endured when a boy, to find the inclination of my little boat increased when I reduced the side of the boat (under water) that swam deepest; and, on the contrary, how unbounded my joy on discovering, that by reducing the side of the boat under water which swam the highest, I remedied the defect. Attach a piece of iron to a round spar in the water, and it will turn round till the weight is beneath: take away the piece of iron, and place a piece of cork or bamboo instead, and the spar will turn round until the lighter body comes to the surface of the water.

A round spar has no stability; whereas a half round spar has the greatest: it will sustain a weight nearly equal to its own, which no other piece of wood of the same diameter can do.

A vessel without stability lays over on her beam ends when hove to in a gale of

wind, in which position the water cannot reach the pumps, which leaks in by the straining of the upper works, scuttles, ports, &c. The rudder is useless, and the vessel unmanageable : in the end, the hatches get stove in by the lee sea, and she becomes water logged.

A vessel made stiff by dead weight, is in danger of a high sea breaking on board, because she does not incline or lie over quickly by the force of the wind, but remains to be struck by the body of the sea ; while the sudden weather roll, in consequence of being so struck, not only endangers her masts, but exposes the deck to the succeeding sea. One sea breaking on board accelerates another, until every thing is washed from the deck ; perhaps the hatches get stove in, and the vessel ultimately founders : whereas a vessel with natural stability, i. e. having buoyancy and stability united, is uplifted and inclined by the base of every approaching sea.

The experiments made by Charles Gorre, Esq. of Weimar, to ascertain the form best adapted for stability, most satisfactorily demonstrates the fact. This gentleman caused

four bodies or models to be made, three feet in length and two in breadth, precisely of the same specific gravity and capacity. One model was square; the second was circular, that is, “ the immersed part was half a circle. The immersed part of the third a flat bottom, with angular sides; and that of the fourth was the form of a triangle or wedge. The second model drew one fourth more water than the first, or square body. The third drew one half more than the first, and the fourth drew as much again as the first.

“ To prove their respective stability, the weight was fastened to a line whose end was made fast to the top of a stick, erected by way of a mast in the centre of each body, and passed over a pully in an opposite station, which worked in a groove to admit of depression, so as to be horizontal with the head of the mast, when the figure became heeled or inclined. The power being thus always horizontally applied, was similiar in effect to the force of the wind.

“ The results of the experiments with a 12lb. power applied, was as follows :—

“ The circular model inclined	19° 40′
“ Square do. do.....	30° 10′
“ Partial triangle do.	35° 12′
“ Triangular do.	37° „

“ When the models were at their utmost inclination, the line was suddenly cut that suspended the weight, to prove the degree of inclination they had to recoil or roll to windward, when it was found that the inclination to roll was nearly in an inverse ratio to the stability, as the circular model hulled to windward,

“ Or recoiled,	33 degrees.
“ The square model,	29 „
“ „ Partial triangular,	27 „
“ „ Triangular,	23½ „

It is evident, from the above experiments, that although the circular bottom has the greatest stability, yet it has the greatest tendency to roll, while the triangular or sharp bottom possesses the least stability, but has the least tendency to roll: therefore a vessel's bottom must have the above qualities judiciously united, which may be done,

1st. By allowing the fore body under water to partake of the circular form; and,

2dly. The after body to assimilate to the triangular form.

And as a vessel of the least specific weight, or which is composed of the lightest materials, is the most buoyant; and since even a tender vessel can be made stiff without detriment to velocity, by adding a temporary planking of the requisite breadth to the fore body, a few feet below the light water mark, to a few feet above the load water mark, commencing at the bow, and terminating at midships; it follows hence, that stability, velocity, and buoyancy can be united in the same vessel.



CHAPTER IV.

Observations, &c. on the Evolutions, &c. of Vessels.



On the Form best adapted to hold a good Wind, and to sail fast by the Wind.

As the pressure of the water increases in proportion to the distance from the surface, it follows, the more water a vessel draws, or the more she is depressed into the water, the greater will be the resistance.

Wherefore,—1st. The lower the centre of lateral resistance is situated, the less will be the leeway or drift. And,

2dly. The lower the centre of displacement is situated, the less will be her direct velocity.

Consequently, the vessel formed to sail by the stern, will sail faster, hold a better wind,

and work better, than a similar vessel formed to sail on an even keel, for the following reasons :—

1st. Because from her centre of displacement being higher, she meets less head resistance, and therefore obtains greater velocity.

2dly. From her centre of lateral resistance being lower, she makes less leeway or drift; and,

3dly. From her centre of rotatory motion being farthest aft, she works better, as will be explained hereafter.

The Virginia pilot boats, the Irish hookers, and similar vessels, formed to sail considerably by the stern, are capable of fetching in, even to windward of the place at which they looked when the tack was first commenced. This arises from the lesser quantity of water that opposes the weather bow and fore body, whereby the natural disposition of the vessel to luff to windward is facilitated; so that, at each 'send and pitch, the fore body is enabled to fall to windward of the place from whence it rose.

This quality is evidenced in the fine formed grabs.

A vessel being trimmed by the head, requires considerable weather helm to keep her out of the wind, when sailing with the wind a-beam, or close hauled: this is owing to the centre of lateral resistance or rotatory motion being removed forward, whereby the impulsion of the wind on the hull, sails, and masts, is so far increased as to act upon the after body of the vessel, similar to a weathercock.

A tender, crank vessel, sailing with the wind a-beam, or close hauled, equally requires considerable weather helm to keep her out of the wind. This arises,—1st. From the increased resistance of the water on the depressed or lee bow, while the resistance is diminished in an equal degree on the weather bow: and, 2dly. By the inclination or heel of the ship, the centre of *direct* impulsion of the wind on the sails is carried to leeward, by which means it has the greater effect to force the vessel up into the wind.

For these reasons, on the near approach of a squall, or as the breeze freshens, the officer of the deck instinctively orders the helm to be put a-weather, to keep the ship from flying up into the wind.

The rudder placed at a great angle, considerably retards the velocity of a vessel.

And since additional breadth at the fore body would produce additional stability, and keep the centre of displacement nearer the surface ; and as the centre of lateral resistance is lowered in proportion as the after body is allowed to descend into the water ; it follows that a vessel, to sail fast by the wind, and to hold a good wind in a sea-way, should be formed to sail considerably by the stern, and to have considerable stability.

*Observations on the Form best adapted for
Tacking in a Seaway.*

The bow sea is the principal obstacle to a vessel coming about in stays. So great is the power of the bow sea, that a vessel sailing with the sea on her lee bow, is frequently forced about against her helm.

Since a vessel sailing by the wind requires weather helm to keep her full, it is obvious, on the helm being put a-lee, at the same time trimming the sails, the ship readily comes head to wind ; and if the vessel holds her headway while in stays,

or until the sea takes the lee bow, in that case the power of the rudder will bring the ship about. But when the headway ceases, it is then the office of the head sails to bring the ship about, because the power of the rudder ceases with the headway, (and remains powerless until the vessel obtains sternway.) Therefore the farther the centre of rotatory motion is removed aft, the greater will be the power of the head sails, when aback, to bring the vessel about; or the farther the foremast is removed forward, the head sails act with greater power on the fore body to force or turn the ship's head over the sea.

I have frequently trimmed a boat when sailing, so that she sailed by the wind, and tacked, without the use of the rudder; this was done in the following manner:—When the boat was to be put about, two or more men were sent close forward, by which means the after body was raised out of the water, whereby the wind acted on the after body with increased power to bring the boat's head to wind. When the boat was head to wind, then the men instantly shifted to the stern of

the boat. Thus the centre of rotatory motion is carried aft. The fore body is at the same time raised out of the water. By which means the sails aback have increased power to box, or force the boat on the steer tack.

Hence it follows (every thing else being the same) the vessel best adapted to tack in a seaway, is that which has the centre of rotatory motion well aft.



Remarks on Steering well, &c.

A vessel that sails fast, must steer well. The rudder has power in proportion to its depth in the water, that is, according to its approximation to the centre of rotatory motion. Captain Schank justly remarks :
 “ that vessels with sliding keels wanting
 “ to veer, are to heave up the fore keel,
 “ and heave down the after keel ; and if
 “ it be requisite to veer very quickly, the
 “ main keel should be hove up also : ves-
 “ sels will then turn or come round as if
 “ upon a pivot, the rudder being used
 “ at the same time as in common cases.”
 The reason of this is plain ; for by the fore and main keels being up, the centre of

rotatory motion is removed aft, which gives liberty to the fore body to yield promptly to the rudder: and as the rudder obtains power in proportion to its depth, it follows, that a vessel, to steer and veer well, should be formed to have her centre of rotatory motion well aft.



Remarks on the necessary Properties for a Vessel to have, to scud in a heavy Gale and tempestuous Sea with the greatest Safety.

A vessel, to scud with safety, must steer well, and rise promptly to the following sea.

A vessel not being sufficiently buoyant in her after body, is in danger of being pooped, or of having her dead lights stove in by every sea; and a vessel that does not steer well, is in danger of broaching to, or in being brought by the lee.

The after body obtains buoyancy, in proportion as the centre of weight is removed forward. If, for example, the centre of weight was two thirds from the stern, the after body would be more buoyant, and rise more promptly to the following sea. Be-

cause, in that case, the after body presents a lever, as it were, to be acted upon by the upward pressure of the sea.

“The worst consequence” (observes Captain Schank, in his remarks on sliding keels) “of a difficulty in steering, is what is to be feared has too frequently happened, though rarely heard of, and that is, the ship’s broaching to. This, though sometimes the consequence of a wild or careless steerage, is more frequently occasioned by strong gales and tempestuous seas. Thus, for instance, a ship scudding before the wind, or quartering, having little sail set, and that low, such as a reefed foresail, when between two seas, is almost becalmed, and therefore loses her way: the next or following sea raises her stern, her bow inclines downwards, the cutwater having a different direction from the intended course. The stern by this is lifted up so high that the rudder has little or no power, it being almost out of the water. In this situation, the ship pressed on her lee bow, by the water having got on the weather quarter, and the ship on the top of the sea, she flies with

“ such violence as to bring her head round ;
 “ and then lying on the broadside, she
 “ plunges with the greatest velocity into a
 “ high or raging sea, the water breaks into
 “ her, washing and carrying away every
 “ thing off the decks, frequently some of
 “ the crew : and it is to be feared that by
 “ such accidents, vessels themselves go to
 “ the bottom, and are no more heard of.
 “ Now there is nothing more clear and
 “ certain, than that sliding keels counter-
 “ act these dreadful effects.

“ To prevent the dreadful accident of
 “ the vessel’s broaching to, no more need
 “ be done, than to heave the main and fore
 “ keels up, and let down as much as is
 “ thought necessary of the after keel ; and
 “ if enough of it is down, it is impossible
 “ that any ship can meet with this.”

Wherefore, a vessel, to scud with safety,
 should be formed to have her centre of
 weight well forward, to give buoyancy to
 the after body ; and to have the centre of
 lateral resistance or rotatory motion well
 aft, to give additional power to the rudder,
 and to prevent the vessel from broaching
 to.

A vessel with her centre of weight or displacement nearest the stern, that is, a full-built vessel, when laden, cannot exceed eight knots; and even then, the eddy water occasioned by the vacuum so far diminishes the power of the rudder, as to oblige the vessel frequently to heave to, in order to avoid the danger of broaching to. In the ship Triton, I experienced a very heavy gale near the Western Islands. We made three attempts to scud; and while scudding, the foresail lifted on both sides alternately, before she would answer the helm; and but that the ship was buoyant, tender, and lofty, the sea must inevitably have broken on board: whereas a vessel whose centre of displacement is farthest forward, that is, having a long and deep run, will sail at the rate of 12 to 15 miles per hour; consequently she can make fine weather, and even make her passage, when a full-built ship is obliged to heave to.

Remarks on the Properties, and on the Form of a Vessel, best adapted to heave to in a violent Gale, with the greatest Safety.

A vessel, to be safe when hove to in a violent gale, must have buoyancy, stability, and steerage way.

Buoyancy, to rise easily over the sea ;

Stability, to enable her to carry sail ;

And steerage way, to admit the vessel to receive the shock of the sea at the best point, from which she would receive the least laboursome motion, and to prevent her from coming head to sea, or from falling off into the hollow of the sea.

Without buoyancy, the vessel is in danger of every sea breaking on board, and strains violently.

Without stability, she will lay over on her beam ends unmanageable.

And without steerage way, the vessel may come up to the sea, and thereby damage or pitch away the masts, or will fall off into the hollow of the sea, where she is in great danger of every sea rolling on board.

When a ship lays too without straining, or shipping seas, then it is proverbial among

seamen to commend the vessel for having 'bow'd the sea.'

The least laboursome motion that a vessel can have, when hove to, is that which equally partakes of the pitch, or rather 'scend and roll; and this motion is given to the vessel when the sea strikes her about 45 degrees before the beam or broad on the bow.

By the extreme breadth being well forward, particularly at the area of flotation, the *base* of the approaching bow sea will then have additional power to incline the ship promptly, and thereby facilitates her rising buoyantly over the sea.

By the centre of weight being well forward, the fore body will oppose increased resistance to the shock of the bow sea, by which means a vessel hove to is less liable to be thrown off into the hollow of the sea.

The advantage in having steerage way when hove to, to allow of the vessel to receive the shock of the sea on the bow, is too obvious to need farther illustration.

The leeway or drift is prevented, in proportion to the depth at which the centre of lateral resistance is situated : and since this

centre descends in proportion as the after body is immersed in the water, it follows the form best adapted to heave to with the greatest safety, is that which has its extreme breadth well forward, and (every thing else being the same) which draws the greatest quantity of water aft.



Observations, &c. on the Position of the Mast.

Since the centre of lateral impulsion of the wind on the sails, hull, masts, &c. is opposed by the centre of lateral resistance of the water, and since the action of the rudder to preserve an equilibrium between those centres considerably impedes the vessel's velocity, it follows that the masts should be placed with reference to the centre of lateral resistance.

If a vessel could be formed to remain upright, sailing with a fresh breeze on her beam, or close hauled, or otherwise, so as to prevent the inclination of the vessel to fly up into the wind; in that case, the centre of lateral impulsion of the wind on the sails, &c. could be placed directly opposite to the

centre of lateral resistance of the water : but as this cannot be done, the centre of impulsion must be placed before the centre of resistance, to counteract that inclination.

Vessels with the least stability, have the strongest inclination to luff up into the wind : consequently the centre of impulsion should be proportionably more forward of the centre of resistance, in tender crank vessels, than in those possessing a greater degree of stability.

Motion in the masts considerably diminishes the propelling effect of the sails. This is demonstrated in a boat under sail, when the oars are also used.

The nearer the masts can be placed to the centre of perpendicular motion, (without the sails on one mast intercepting the wind from the others,) the greater will be the propelling effect of the sails, and the less the masts and vessel will labour and strain.

A vessel formed to stay well, admits of her foremast being placed proportionably more aft, or nearer the perpendicular motion : witness many of the brig privateers out of America.

Masts that rake aft, give to the sails a tendency to raise, and assist the vessel over the sea. To be convinced of this, we have only to call to mind the effect of the wind on a boy's kite, in the act of flying. Besides, by having a rake aft, the masts are less liable to being pitched away.

Long lower masts and short topmasts are far preferable to short lower and long topmasts.

1st. Because they can be rendered doubly more safe and secure from being carried away. The difficulty and anxiety to secure a long topmast, while the vessel is labouring in a high cross sea, is known to every experienced seaman.

2dly. Because long lower masts admit of lofty and large trysails being set : which sails are preferable, for heaving to with, to either the main topsail, courses, or staysails, in so far that they give the vessel steerage way, and at the same time allow her to lay within five points of the wind and sea. Whereas, when hove to under the close reefed main topsail, from not having steerage way, she comes up and falls off at pleasure. And when hove to under

the foresail, she lays nearly in the hollow of the sea, and under the staysails the vessel cannot be kept steady, from their being too low. Besides, a vessel hove to under trysails is in no danger of going down stern foremost, when taken aback. Withal they are much easier taken in, and with less risk of splitting in a gale of wind; then either the topsail or foresail.

And, 3dly. The long lower mast, by admitting a pole topmast and topgallant mast (in one spar) to reeve and fidd, the topmast caps, the heel of the topgallant mast, and in many cases even the topmast crosstrees, could be dispensed with. The relief thus given to the masts by this reduction of weight from the mast head, may be accurately estimated by those seamen who have witnessed the relief afforded to the masts by sending down the topgallant yards in a cross jerking sea.

*Remarks on Vessels intended to navigate
in shallow Water.*

It was seen, that a vessel intended to

work off a lee shore, and to sail fast by the wind, must be deep in the water to hold a good wind; and it is manifest, that a vessel intended to navigate in shallow water, must have a flat floor, that is, a flat bottom, in order to draw the least water.

Vessels with a flat floor, similar to the bottom of the transit constructed by Capt. Gower, are admirably adapted to navigate in shallow water. Auxiliary means must be resorted to, however, to supply their want of depth, so as to increase the lateral resistance of the water, as well as to give the centre of rotatory motion its proper position. This can be done by means of two or more additional keels or bilge-pieces, sliding keels, or lee-boards.

These vessels may preserve the same form in every other respect, save their flat bottoms, as those vessels intended for velocity, and to work off a lee shore in a heavy sea.

Riding at Anchor.

A vessel that goes smoothly through the water, has sufficient buoyancy, sails

fast, and steers well, must ride easy at anchor.

Conclusion.

In the preceding observations, it has been demonstrated,—

1st. That velocity is produced, in proportion as the run is lengthened and the vessel is water borne.

2dly. That breadth, &c. gives stability and buoyancy.

3dly. That depth, that is, the after body being deep in the water, enables the vessel to hold a good wind, to work, to scud, and to steer well, and prevents the rolling motion. And,

4thly. That the nearer the centre of displacement is to the surface, the less will be the resistance of the water.

Therefore, by carrying the extreme breadth well forward,

1st. Admits of the run being made proportionally long.

2dly. Gives the least laboursome motion to a vessel hove to in a heavy gale, and facilitates her rising buoyantly over the sea.

3dly. Prevents the fore body being depressed into the water ; at the same time it admits of the after body descending to its required depth. And,

4thly. Admits of the centre of weight being carried forward.

Hence it follows, that vessels should be formed with their extreme breadth well forward.

It was likewise demonstrated,—

1st. That in proportion as the centre of displacement or gravity is removed forward, or from the stern of a vessel, (every thing else being the same,) the greater will be her velocity.

2dly. That a vessel goes smoothly through the water, that is, has the least pitching motion, in proportion as she is water borne, and as her centre of weight is carried forward.

3dly. That in the act of scudding, the after body obtains buoyancy, in proportion as the centre of weight is removed from the stern. And,

4thly. That a vessel hove to in a tempestuous sea, would be less liable to be

thrown into the hollow of the sea, in proportion as the centre of weight is forward, to oppose and withstand the shock of the bow sea.

Wherefore vessels should be formed to carry their centre of weight or gravity well forward.

It was also demonstrated,—

1st. That a vessel, to work well, to hold a good wind, to tack, veer, and to steer well, must draw considerably more water abaft than forward.

2dly. That when sailing by the wind, or hove to, in a heavy gale, a vessel receives less bow and head resistance, in proportion to the lesser quantity of water she draws forward.

Hence it follows, that vessels should be formed to have their centre of rotatory motion well aft.

Therefore the art of Marine Architecture consists in the proper disposition of the centre of gravity and centre of rotatory motion: and that vessel is the most safe and perfect sea boat, which has the greatest distance between those two centres, (every

thing else being the same ;) that is, whose centre of gravity is the nearest the head of the vessel, at the same time having her centre of lateral resistance or rotatory motion equally aft, or near the stern.

FINIS.

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