HOW TO DESIGN A YACHT.

HOW TO DESIGN A YACHT.

BY

CHARLES G. DAVIS.

NEW YORK & LONDON
THE RUDDER PUBLISHING CO.
1906.

FROM THE PRESS
of

THOMSON & CO.
9 MURRAY ST.
N.Y. CITY.

INTRODUCTION

THE art of designing vessels—that is, of drawing their forms upon paper—is old, much older than most people suppose. It is more than probable, although we have no records to show it, that the ancients so delineated their craft. As early as the Fifteenth Century it was

The result has been a constant and generous advancement of the art. To-day, vessel designing, instead of being the property of a few, its practice carried on behind locked doors, is the possession of the many, and the rudiments of the art can be acquired in a hundred technical schools.

In the early days, a few books dealing with ship designing and construction were published, but they are extremely crude and owing to the expense of engraving

know and what he cannot find out in any other treatise on designing.

It is for such persons, those who take up the art for amusement and not as profession, this book is intended.

EDITOR.

ERRATA

Page 13. Table of Offsets, Raceabout, Section 8 should read 1-6-7.

Page 30. Fifth paragraph should read: cubic feet of water; sixth paragraph should read: cubic ft.; seventh paragraph should read: 2 x 2 x 1 = 4 cubic ft.; eighth paragraph should read: 20 x 8 x 2 = 320 cubic ft.; ninth paragraph should read: 35 x 14.5 x 3 = 1522 cubic ft.; 46.2 x 15 x 7.5 = 5197 cubic ft.

Page 31. Top line should read: "only 435 cubic ft., or 28% of 1522;" second paragraph should read: "Her length x breadth x depth gave 5197 cubic ft., but she only occupied 12½% of this, or 645 cubic ft."

INTRODUCTION

THE art of designing vessels—that is, of drawing their forms upon paper—is old, much older than most people suppose. It is more than probable, although we have no records to show it, that the ancients so delineated their craft. As early as the Fifteenth Century it was the practice of shipwrights to lay down plans of vessels, and a large number of such designs are in existence. Many of these are of very fine vessels, and are excellently drawn. It is probable that the art, as we know it to-day, originated in Italy, possibly in Venice or Genoa, cities whose shipwrights were the most advanced of any in the world at that time. There is to be seen a splendid series of drawings made by an Englishman in the Sixteenth Century, showing some remarkably fine-lined galleys.

One reason that the art of designing is supposed to be recently modern, is due to the jealous care with which its methods were concealed by those who understood the science. Like the religious secrets of the Egyptian priests, it was shrouded in the darkness of oath-imposed secrecy and handed down from father to son, or from master to apprentice. Except in rare cases, the designs were never allowed to be published. This practice continued to a late day, and is still kept up by some designers. But a more liberal and progressive body of men gradually worked into the business, and casting aside the old and selfish practices, gave freely to the world their labors. The result has been a constant and generous advancement of the art. To-day, vessel designing, instead of being the property of a few, its practice carried on behind locked doors, is the possession of the many, and the rudiments of the art can be acquired in a hundred technical schools.

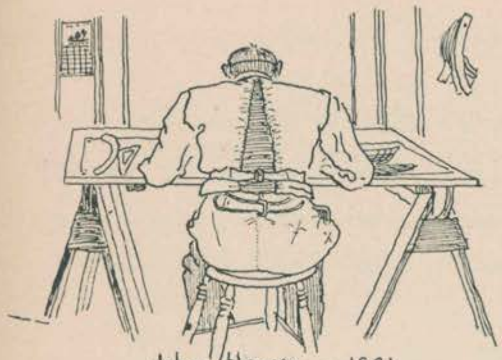
In the early days, a few books dealing with ship designing and construction were published, but they are extremely crude, and owing to the expense of engraving but very sparsely illustrated. Usually there is only one or two designs given. Yacht designing, as we have it at present, was first begun about sixty years ago in England; a small book was published on the subject by a man named Marett. This was for years the standard text-book. The next work of importance was that written by the late Dixon Kemp, which is to-day the leading work upon the art.

But all these books are written high over the head of the average man, and are intended for professional consumption. The writer, himself thoroughly comprehending the subject, cannot get down to the simplicity of explanation that is necessary to the beginner, who is totally ignorant of even the first rudiments. For years I have endeavored to get somebody to write a Yacht-Designing Primer, that would start off teaching the A, B, C. I know of no man who is more capable of doing what is wanted than the author of this book; he, more than any man, understands what is needed, and has the power of explaining intricate and profound practices in extremely simple language. Being largely self-taught, he comprehends what is necessary for the beginner to know and what he cannot find out in any other treatise on designing.

It is for such persons, those who take up the art for amusement and not as profession, this book is intended.

EDITOR.

TABLE OF CONTENTS.



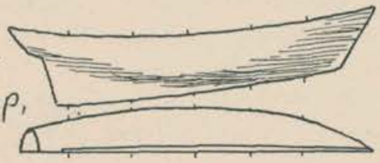
John Harvey - 1891.

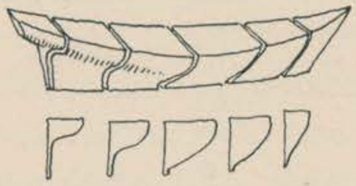
DESIGNING.

Let us suppose you want to build a certain kind of a yacht and haven't the time to do the work of constructing the boat yourself. To so draw out the plans that a boat builder may take them and build her for you is evidently quite an art.

It is the yacht-designers' or, as some call themselves, naval-architects' work to prepare such plans.

Even if you are going to build her yourself it is the only correct way to go about it. Years ago when everything was built by "rule-o'-thumb" and only the simplest kind of calculations were made, the builder used to whittle a model of the purposed craft, mark out her outline and enlarge it to full size to get the shape of her keel, stem, stern, etc. Then saw the model up into several sections to get the shape of the boat at intervals along her length.



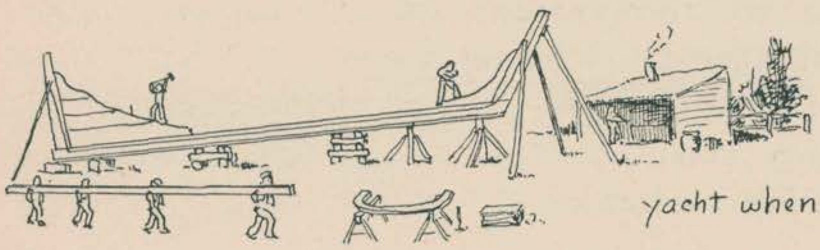


So, when the keel was set up, he could set enlarged moulds made from these small patterns at their proper distances along the keel. Then by bending strips of wood, called ribbands, from bow to stern around these moulds he could fit in timbers at any intermediate position desired.

That kind of work is all right if, as it was in those days, every boat was built from one conventional model, the proportions only being changed.

All boats were then built on a straight stick for a keel, and others for stem and stern post set to a certain angle and one mid-ship section would answer for nearly all boats, but today there are as many different shaped yachts as there are men owning them.

Though every model may be different the operation of designing is the same - the rules for figuring the various elements necessary to decide the actions of the yacht when built are all based on



.on one set of rules and are just as positive as any rules in arithmetic.

The only variable element that enters into the work is the matter of personal experience, which is different with every person and always will be, so long as Americans live in America and the Dutch in Holland. Nine-tenths of designing is a matter of judgment and experience.

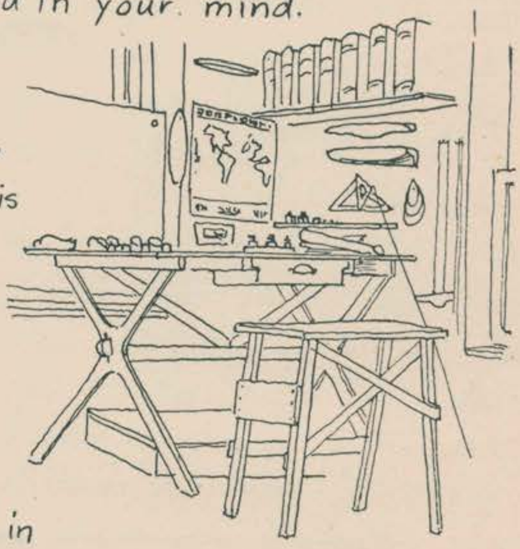
"In America."

"In Holland"

For instance, one of the first questions that arise when you decide to design your first boat is - "What size shall she be?" Others immediately follow. "Shall she be a center-board, keel, or fin-keel boat?". "What beam, draught, etc?"

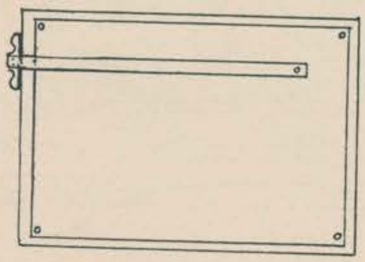
We will assume you have looked over enough boats and measured several that were close to your ideal, so that you have the sizes and an idea of just the kind of a boat you want fixed in your mind.

Pin out flat on a drawing board a sheet of paper of such size as will enable you to draw your yacht on large enough a scale to measure accurately from. Boats such as it is our intention to treat on, viz:- under fifty feet water line, can be drawn on either of two scales, as follows; up to thirty feet water-line on one-inch scale over thirty feet on half-inch scale.



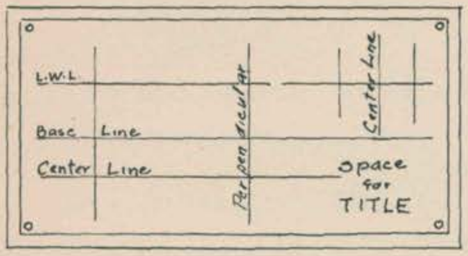
A Designer's Corner.

With your tee rule on the left edge of the drawing board, draw a horizontal line in blue ink to represent the water level. Leaving room between it and the top of the paper to give room for the boat above water, say about four or five inches.



Below this, a little deeper than you intend the boat to be, draw another line in red ink as a base line to measure to. It is better to always draw the base line below the keel a little, as all boats have to be blocked up off the ground a short distance, and this puts your base-line so there is a space for these blocks.

Below the base-line draw another red line as a center line for the deck or half-breadth plan a little more than half the width of your boat below the base-line.



Paper ruled for plans.

In merchant ships the length as measured for tonnage is the distance from the forward side of planking on the stem to the after side of the stern-post. This distance is termed "between perpendiculars", but in yachts where the length measurement is usually taken on the water line this really becomes the distance between which the designer is to work. So allowing space for the after overhang at the left edge of your paper square up a fine red-ink line for the after perpendicular and the length of your water-line away to the right of it, measured of course by the scale to which you are designing the boat, square up another red ink line.

It is usual, although not by any means necessary to design yachts with their bows always pointing in one direction principally so that comparisons may be made between two designs. Most boats are designed with their bows on the right. To the right of these plans leave paper enough to draw the shape of the boat end on.

With the center-line, base-line, water-line and perpendiculars, you are ready to begin the real designing - here comes the first test of judgment, backed by experience.

"How much free board shall be allowed from the water-line to the sheer line?"

Let us look into the question. There is no iron-bound rule or law that says how much or how little free board you shall have, unless you are designing a racer for some such organization or club as The Massachusetts Yacht Racing Association, where a minimum freeboard is stated for each class of boats in their rules. This is a very good thing, as it prevents building a racer so low-sided that she would be a wet, unsatisfactory boat for ordinary use.

Outside of such clubs this freeboard question is left for your own decision.

Narrow keel craft usually have more freeboard than the wide-center board boats. Boats intended for use on the Great South Bay or small bodies of water need less freeboard than those intended for rough ocean work.

A River Tow-boat

The Cape cats, for instance, are very high-sided; and all cruisers, as a rule, have more height out of water than the racers, as the


An Ocean Tramp.

latter want to expose as little surface as possible to the wind on account of the resistance it produces, also the unnecessary weight of the top-sides. A swimmer swims easier the less he has of his head above water -- but then again you want good freeboard on the cruiser, as she stays out and rides seas that as a rule send the racer scurrying for home as soon as the sailing necessary to complete the race is over. Comfort usually leaves the ship when green water gets washing along the scuppers on deck.

A set of proportions showing the relative height of freeboard compared to the beam of various kinds of boats is given in the following table.-

This gives you the data from which to decide the first question that arises, the least freeboard.

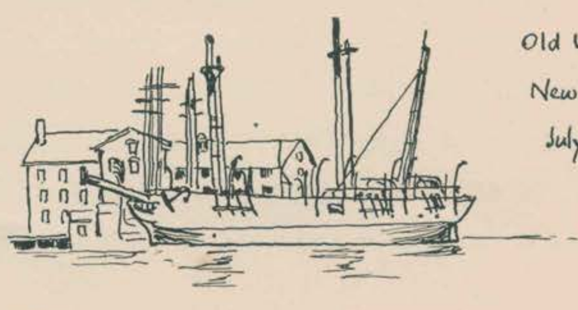

Old Whalers
New Bedford
July-2-1894.

TABLE GIVING PROPORTION OF FREEBOARD TO BEAM.

FOR VARIOUS KINDS OF YACHTS.

South Bay Cats	(for shallow water)	about 20' w.l.	Freeboard (least)	is 1/9	the beam
L.I. Sound Cats	(for general use)	about 20' w.l.	"	" 1/7	" "
Cape Cod Cats	(for ocean work)	25 to 30' w.l.	"	" 1/5 to 1/6	" "
Sloops	(for general use)	25 to 30' w.l.	"	" 1/5 to 1/6.5	" "
Small Yawls		about 25' w.l.	"	" 1/4.5 to 1/5	" "
Large Yawls		25 to 50' w.l.	"	" 1/6 to 1/6.5	" "
Schooners		45 to 50' w.l.	"	" 1/5 to 1/6.5	" "

"But where, in the distance between the two red perpendiculars shall this point of least freeboard be?"

"What shape shall the line, representing the edge of the deck at the side, assume fore and aft?"

This line is known to sailors as the sheer line.

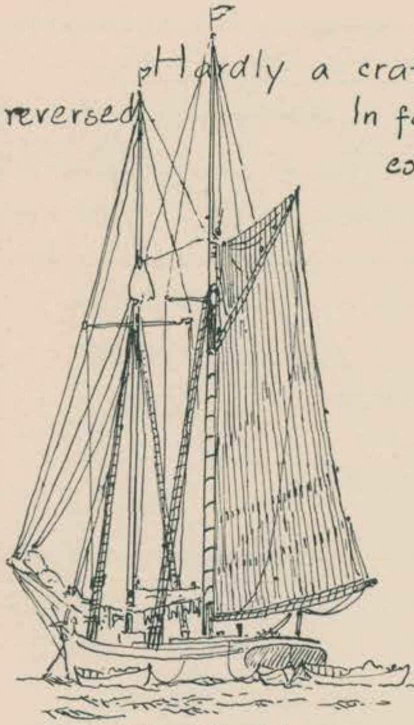
In ancient times the stern of the ship was always the higher. as is illustrated in the "Arab dhow", "Chinese junk, Malay felucca, old Spanish galleons, and even in our own old time ships. Ships of all ages where it was a hand-to-hand warfare on deck have the stern, the end where the officers live, much higher than the bows. This really was the fort into which, when the enemy secured a foot hold on their deck, the officers and crew retreated, and from this elevation had an advantage over the enemy on the lower, forward deck.

Relics of the idea that the stern should be the highest, are to be found in the old Hudson River brick-sloops and schooners.

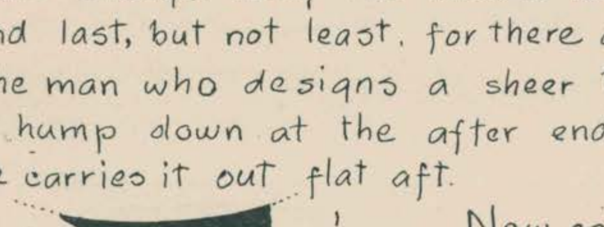
  

Hardly a craft is built now-a-days but what this condition is reversed. In fact the modern yacht is better-looking with the lowest point of her sheer about 1/10 of her water line forward of the after perpendicular.

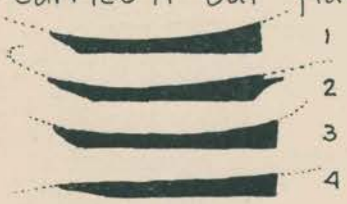

The Gloucester Fisherman "Kearsarge" - 1894

The rougher the water the yacht is intended to sail in the higher in proportion is the bow to the sheer. Boats for very smooth water need little or no sheer and can be very low forward, but a fair amount of sheer always makes a better-looking craft. It is like a man's handwriting, this sheer question. You can almost tell who designed a yacht by her sheer.

A Watson steam yacht stands out clear of the fleet about her by the sweet proportions of her sheer. and ends. Just as one American designer's work can be recognized by the straightness of his sheer. In sailing yachts there is the same distinctions;- the designer who uses an arc of a circle for his sheer, only of course the bow is higher than the stern and this throws his least. freeboard just a little aft of the middle of the water-line length.



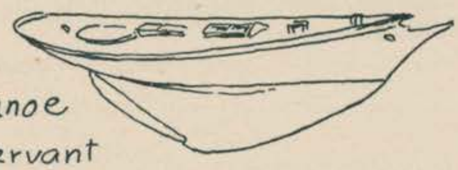
The man who uses a section of a parabola - beginning very straight forward and gradually increasing in curvature towards the stern, and the man who makes his sheer line quite straight along the middle with a quickening curve at each end. and last, but not least, for there are altogether too many such examples, the man who designs a sheer that when built into wood appears to hump down at the after end like a broken-backed, boat because he carries it out flat aft.



Now each one of these sheers are fit for a certain kind of a yacht, except the last, and that is faulty, as I will explain in its turn.

No-1. The arc sheer, is all right on wide models where the side line is also much on the arc shape, Such as the old style sand-bag cats and sloops and most of the American center-board boats that were built before long ends came into vogue.

No-2. The parabolic sheer is the prettiest and best; it keeps the forward part of the boat higher above the water, and the graceful up curl at the after end gives a spring and lightness to the after overhang. This is the best sheer for everything but a very wide boat.



No-3. If the boat has a parallel shape with short ends the third sheer is best, such as on a canoe or canal-boat. If you have been observant and used your brain you may have noticed that there has to be a certain likeness between the sheer and side or half-breadth shape.

An arc sheer takes an arc side line, a parabolic sheer takes a similar side line, a straight sheer with a curl up at each end fits a boat whose side line is long and straight with bluff ends.

No-4. Is what the boat will look like if the sheer be an arc and the stern pinched in quickly. The one line influences the other, with the result shown in the diagram. Such a result means No-4. should have had more sheer aft.

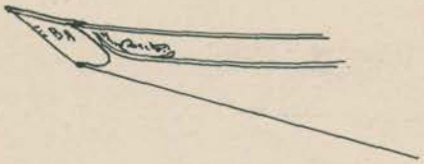
A few examples of various sheer lines may here be of some assistance to the novice. By dividing the distance between perpendiculars into ten equal parts and drawing vertical red ink lines you have, counting the forward perpendicular as number one-eleven such lines- By measuring up on these lines from the L.W.L. the following dimensions the different sheers can be reproduced.

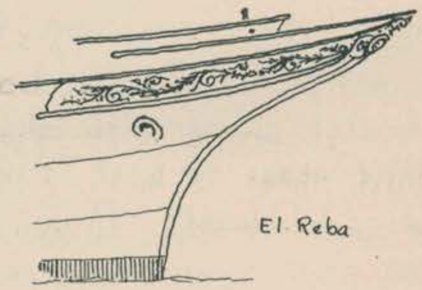
Boat	Designer.	1	2	3	4	5	6	7	8	9	10	11	
Keel Sloop	Wm Gardner.	2-4-0	2-2-5	2-1-0	1-9-8	1-8-6	1-7-5	1-6-5	1-6-0	1-5-7	1-5-5	1-6-0	
Raceabout	B.B.Crowninshield	1-11-0	1-10-1	1-9-0	1-8-4	1-7-6	1-7-7	1-6-2	1-5-7	1-6-0	1-6-0	1-6-6	
Cat Boat	W.L.Force	2-3-4	1-11-0	1-7-4	1-4-2	1-1-6	1-0-0	0-11-0	0-10-6	0-11-2	1-0-2	1-2-0	
Fin Keel	Chas.Olmsted	2-4-1	2-2-5	2-1-0	1-11-5	1-10-4	1-9-3	1-8-5	1-8-0	1-8-0	1-8-3	1-9-0	

The heights of bow and stern are largely matters of personal judgment, rather than any fixed rule and give that individuality to a boat which enables you to identify her with a certain designer.

Measure off as much overhang as you want your boat to have at each end, the after overhang usually being a little longer than the forward one, and sketch in such a shape bow and stern as your fancy dictates.

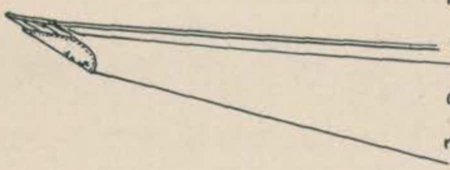
Every one who is interested enough in the subject of yacht designing to go to this extent, is sure to have some decided ideas about boats, now is the time to advance them.

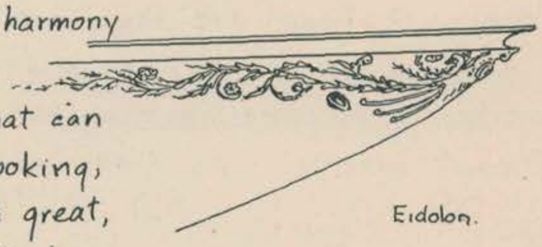




El Reba

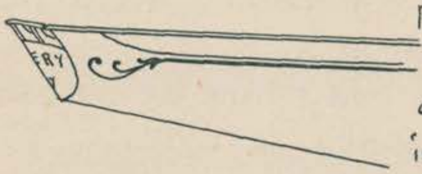
From the simple little plumb-ended cat-boat to the elaborate steam yacht there is a certain harmony of proportions and angles for each that can make a complete-looking, tidy little craft, or a great, ugly-looking, unfinished appearing one.

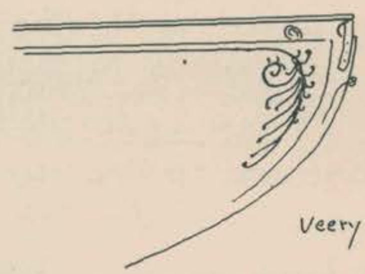




Eidolon.

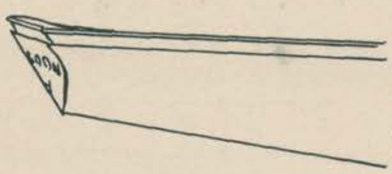
Styles appear and disappear in yacht building as in every thing else, and so always aim to turn out a stylish, up-to-date boat.

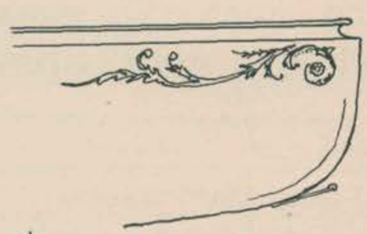




Veery

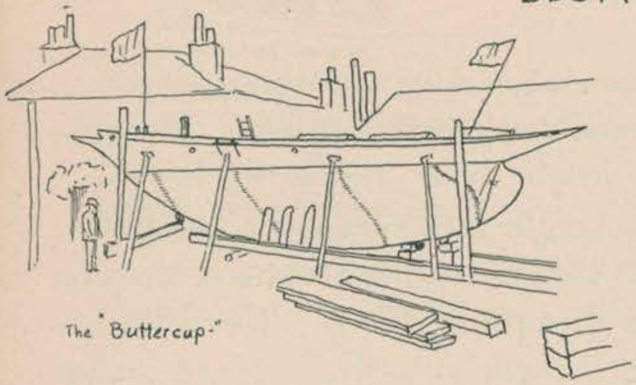
But do not sacrifice the utility of the yacht for the purpose for which she is intended, to style.





Dragoon.

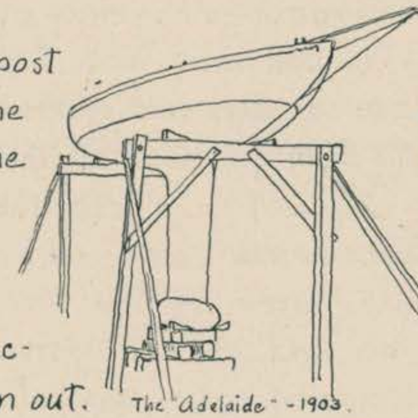
With the sheer and bow and stern overhangs sketched in all the above water part is settled. Then decide on the draught of water you want her to have and sketch in an outline of the bottom of the keel.



The "Buttercup."

If she is to be a keel boat, remember what difficulties are liable to be met with, such as getting aground, unhandiness in hauling out to paint or lay up for the winter, etc., and try and overcome them. Enough keel for the boat to stand on in case she should get aground is a good point to remember, and the angle of that keel on the bottom such that the yacht will not pitch-pole head first and go bows under as the tide leaves her. Also, remember, the keel has to go through the water as fast as the hull, and don't get it so large in area as to make the boat sluggish in dragging it.

The rake of the stern-post and forefoot, next take our consideration; but the novice had better draw them to suit his eye until he has taken up that subject of yacht construction, which is so complicated that nine-tenths of the amateurs, leave its study entirely alone and merely design a form, leaving it to more practical heads to build the impossibilities they turn out.



The "Adelaide" - 1903.

The two studies should go hand in hand, as it is just as important to know whether it is possible to build a certain shape as it is to know how to draw that shape. Often a builder sees changes that could be made that would not alter the boat's shape any but would save the owner many dollars, just because the designer lacked practical experience.

With the profile now complete the half width of the boat comes next. The amount of beam she shall have, and how quickly or slowly that beam shall diminish towards the ends. "Beam", as I myself have often remarked, "never hurt any vessel." But too much draught often has. If a vessel were to be used as a light-ship or a spar-buoy to ride still on the water, it is obvious that the more bulk there is deep down under water the less there is above water to pitch about. But boats being intended to move through the water, meet with great resistance if their bulk is carried very deep in proportion to their length

OFF CITY ISLAND

Jan-9-1892


A Whaleback - oil Tank.

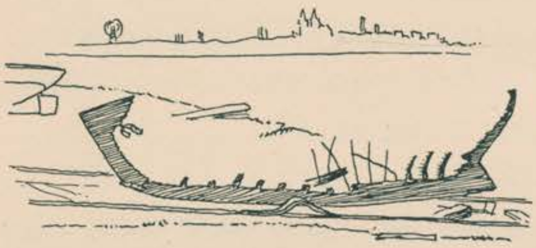
To form an idea of about what beam should be used on different kinds of craft a comparison of the measurements will show that:-

Cat-boats for shallow water the length is 3 times the beam.
Cat-boats for rough water the Length is 2 to 2½ times the beam.
Center-board sloops the Length is 3 to 3½ times the beam.
Keel sloops the Length is 4 to 5 times the beam.
Yawls the Length is 3½ times the beam.
Schooners the Length is 3½ to 4 times the beam.

For instance, the Lucile is 21' over all and 7' beam. - Her length is just 3 times her beam.

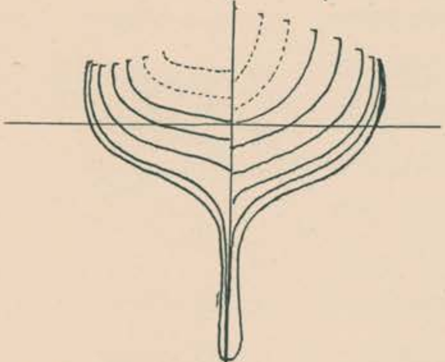
The Harbinger was 28' over all and 13' 6" beam. Poor old Harbinger. I was laid up in bed, had run a nail in my foot that day, when about nine o'clock in the evening the fire bell rang and I heard the fire-engine coming down the street. I could see a glare out of the window in front of me, over in the Knickerbocker Athletic Club grounds at Bergen Pt., Bayonne, N.J., I knew there was no house where I could see the firemen fighting the flames. Next day I hobbled over to the beach, and there was the charred remains of what I always looked upon as the best cat-boat ever built. A fire-bug had put kerosene on her and set her afire - He is now in jail.

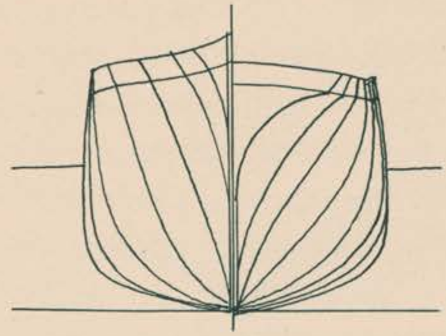
To resume our designing - By this rule take the length over all and divide it by the figure given to find the beam.


Harbinger after the fire.

When the beam is decided, we have the same question to decide that the sheer presented. "Where shall be the widest part?" "How far from the bow or stern?" Here all ordinary data fails to show the answer and judgment is required. About ninety per-cent of the yachts are widest just aft of the middle. In designing ships the middle for quite a length is of a parallel shape, like a box with short bow and stern rounded off on it; this is so as to give as much cargo space as possible on a given length.

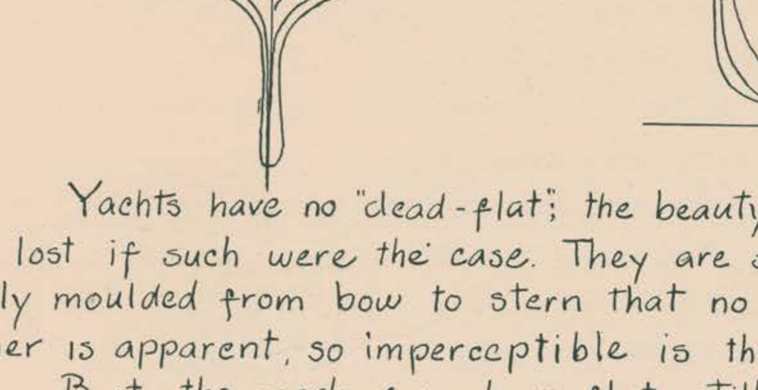
This flat part is called the "dead-flat" and in designing the shape of the frames for the bow and stern when they come to this midship shape they designate it with a mark, thus:- 𝔛, illustrating that this one frame is the shape of the boat along in the middle.



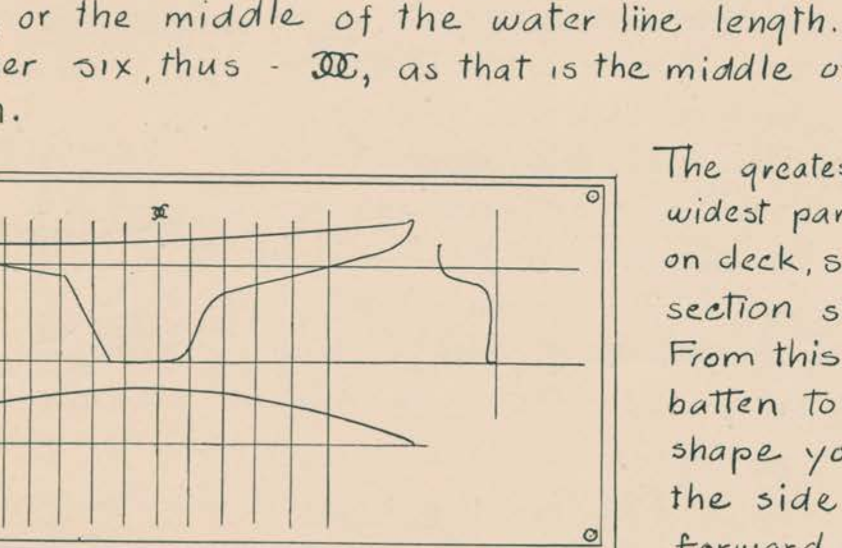


Yachts have no "dead-flat"; the beauty of the yacht model would be lost if such were the case. They are supposed to be so beautifully moulded from bow to stern that no change from one to the other is apparent, so imperceptible is the blending.

But the mark for dead flat still survives; more to mark the change of bevels from the forward and after bodies, than anything else, or the middle of the water line length. So mark section number six, thus - 𝔛, as that is the middle of the waterline length.



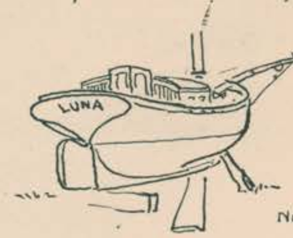
The greatest beam, the widest part of the yacht on deck, should be on section seven.
From this point bend a batten to illustrate the shape you purpose for the side line, ending forward at the end of the stem and aft at the half width of the transom, which is usually about half as wide as the boat is amidships.



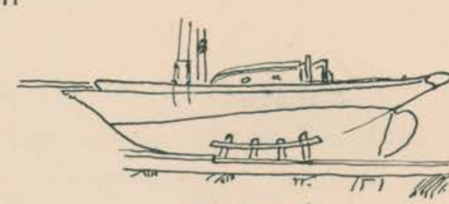
off City Island.

When the sheer and side line are drawn satisfactorily to your eye transfer the width and height of section number seven to the space you have ruled off for the body plan on the right of the sheer plan

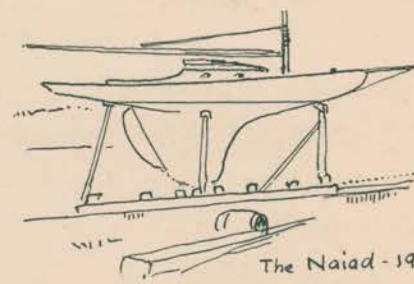
Draw all the bow sections on the right-hand side of the center line and all the stern on the left. As number seven is the largest section, it corresponds to the dead flat of a ship. This is the first section in the after body. Mark a spot where its width and height meet. Then transfer the depth of keel on section seven to the center line in the body plan.



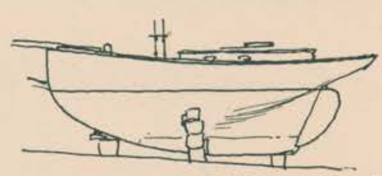
Nov-89

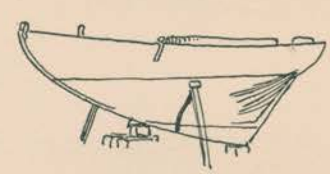

The Manito

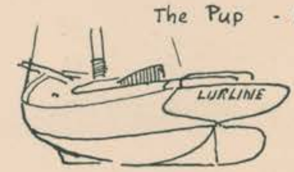
Between these two points you are to sketch the shape of the yacht as near as possible to what you think is right for her 'midship section, Remembering always that a square, flat bottom gives stability and a circular shape has little or none. That the more surface there is exposed the more surface resistance the boat will have.


The Naiad - 1903.

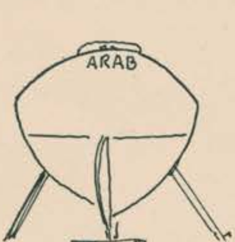
The question of mid ship sections call for a knowledge of the stability of boats, which is in itself a subject to be treated at length, - and might as well be explained now, when it first came up, as later.


The Beth July-1890

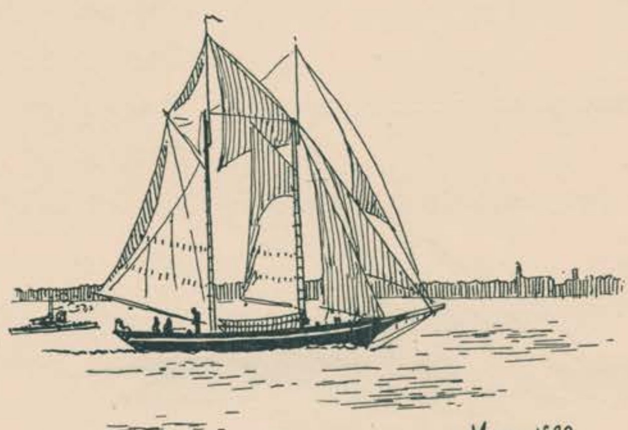

The Pup - 1894



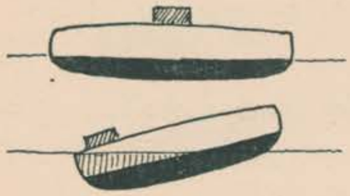
Nov-1889



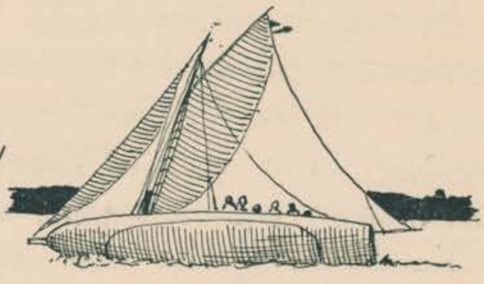
- 1889


May - 1892.
Off Bay Ridge

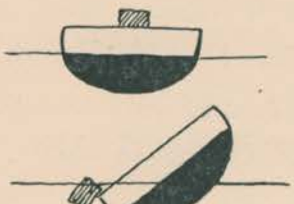
We will begin with the scow model, wide and shallow, such as the modern small racers now have. This gives the greatest amount



of stability, because when any weight is moved off to one side the shape of the boat is such that it quickly increases it's bulk away out near the edge to sustain that weight.

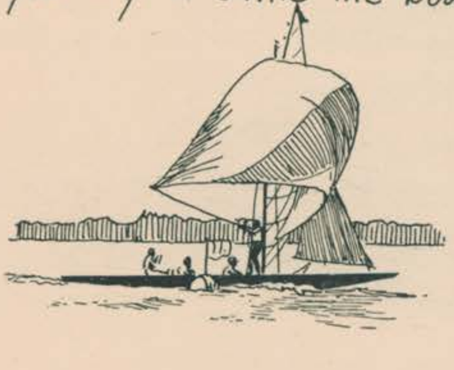


The Cartoon— 1899.



Where as a circular shaped section in a boat gives no such increase in the shape of her bilges to help hold up the weight, but is the same shape, no matter how far she is heeled over. She will roll over until she dumps the weight off the edge.

Small racing boats, where the crew's weight is sufficient to hold her up against the wind, often have a saucer-shaped section, and are very fast and stiff up to the time when the deck edge begins to go under; they then are the most dangerous. If you try to luff them, the stern, the end which has to move by the action of the rudder, in trying to turn only cuts deeper under water and a capsize is sure to result - unless you can relieve the pressure and let her come up near enough to a level keel to bring the deck edge above the water. Another way is to put your helm up and run off before the wind. This tends to turn the stern up and out of the water, but in doing so adds to the pressure on the sails and sometimes capsizes the craft. It is all right to wear off before the wind, provided you try it while the boat still has full headway on her and is not half stopped by her decks dragging under.



The safest way, when knocked down so the deck goes under, is to let the jib-sheets fly and so relieve the bow and let her come into the wind, without cutting her side under by the action of the rudder.

There is so little buoyancy in the lee side of such a model that as soon as they get up on edge they sink deep into the water before there is enough boat to sustain them.

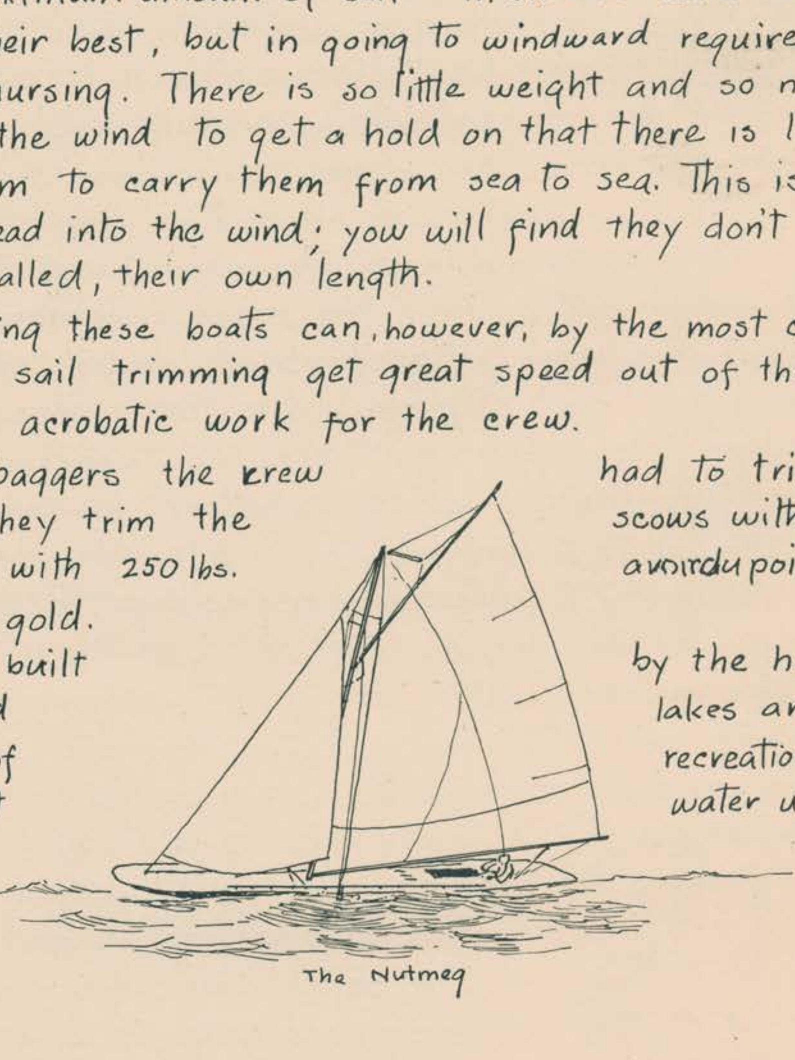
But up to the time when they can just keep their lee deck clear they are, with the enormous sails they are able to carry and the small amount of boat there is left to drag in the water, most of it being lifted out when she heels, about the fastest kind of boats afloat.

With the wind abeam or on the quarter these long, shallow scows sailing on one long edge only have the minimum resistance, and are able to carry the maximum amount of sail. In smooth water and hard winds they are at their best, but in going to windward require the tenderest kind of nursing. There is so little weight and so much big kite-like frame for the wind to get a hold on that there is little or no momentum to them to carry them from sea to sea. This is demonstrated by luffing dead into the wind; you will find they don't carry, or fore reach as it is called, their own length.

An expert at sailing these boats can, however, by the most careful kind of steering and sail trimming get great speed out of them to windward, but it is acrobatic work for the crew.

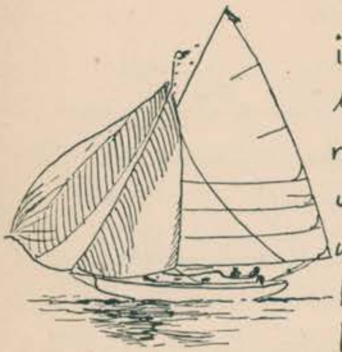
In the old sandbaggers the crew had to trim her with sand-bags; now they trim the scows with human weight, and a man with 250 lbs. avoirdupois is worth his weight in gold.

These scows are built by the hundreds now on all the inland lakes and furnish the healthiest kind of recreation - but as sea-boats for salt water use there are better.



The Nutmeg

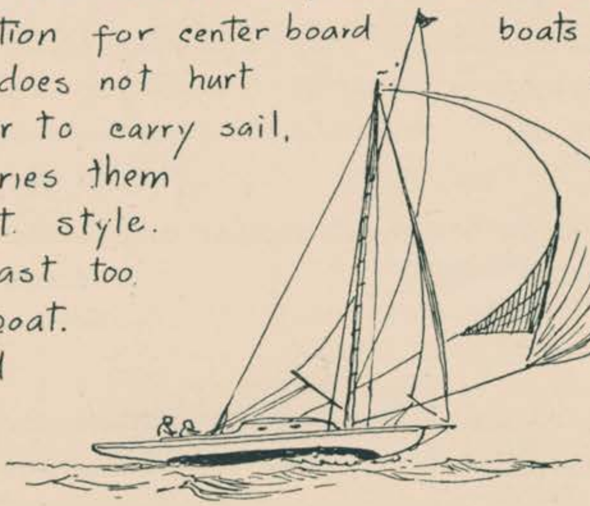
The Helen



Next comes the high-sided scow, a step in the line of improvement from the skimmer we have just discussed. More of a rough-water boat. In smooth lake sailing it is naturally the lightest boat that will win, but when the waves begin to form the boat that has more freeboard will keep the weight of water off her deck and retain her buoyancy longer than the one that cuts under to leeward.

In light winds the high-sided scow had more weight to carry and more wind resistance on the hull, and is not as fast, but now she has the better of it. and if properly designed will have as much buoyancy in her side, due to the lengthening, as the overhangs come into the water and the high freeboard, as she had in her bottom when upright.

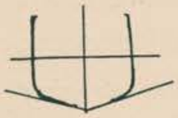
Such boats as these sail faster, however, if a reduction is made in their sail When they begin to roll the weather side high up in the air they will go better to windward if sail is reduced, and they are not allowed to heel over so far. But with a free wind running they will carry all the sail the law allows, and more too.

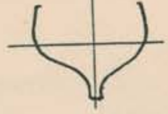


This flat section for center board boats makes the fastest kind of a craft. Ballast does not hurt them, either, but gives them a wonderful power to carry sail, and a momentum when started that carries them bounding through the seas in great style. But do not concentrate the ballast too much; spread it out in a flat boat.

Having treated of almost flat boats we will now look into those that will have what is called "deadrise." Old time ship-builders used to give all their ships a certain amount of V-shape to the bottom.

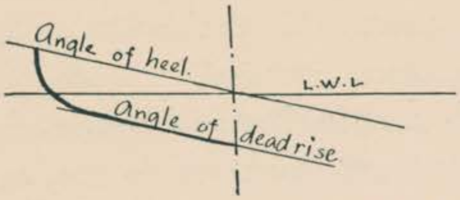
Some gave the bottom an angle of, say, 3 degrees; some 5 degrees, all according to their own personal experience in having built some ship that had a certain angle. If she was the most successful ship, in all probabilities the angle of dead-rise she had. would be found in nearly all that builder's future boats.





In yachts, where every man has a right to design as he chooses, and cargo carrying does not limit him, many a funny shape has been produced by the men who knew just enough about designing to know nothing.

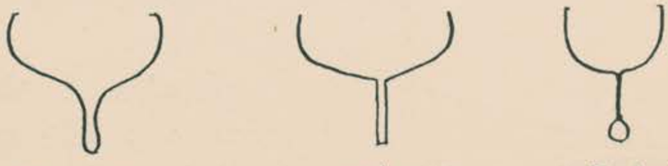
In center-board boats the angle of dead rise is usually about equal to that angle of heel, that just puts the lee rail flush with the water. In keel boats the dead rise is so variable, and so little of any one angle is to be found throughout their length, that it is not worth consideration.



A great many people make the mistake of putting a keel on a boat never intended to carry one. They seem to think anything is a keel boat if you only bolt a keel on it. But this is no more true than you can make a chicken out of a dog by sticking feathers on him. You may make him resemble a chicken but his actions will be decidedly dog-like; just so with boats.

The center board and keel boats are two distinct types; one obtains its stability by its width, the other by its depth with a lead pendulum on it.

There are three kinds of keel boats. The true keel, the slab deadwood keel and the fin-keel. The first is the most popular and best all around.



True Keel — Slab Keel — Fin Keel

The second is a cheap method of imitating a keel boat, but gives a boat so much surface that the skin resistance is a great detriment to their speed. Theoretically the fin-keel is the perfect boat, combining the greatest stability with the least resistance; but few designers can turn out one that is perfect. When they are right, they develop grea. speed—as, for example, the Herreshoff design Larchmont 30's, the 21's and El Chico and Dilemma, the fore runner of them all.

The secret of the design lies in the fact that the shape of their hulls should be an elongated ellipse; so that when they heel over they do so evenly, and do not depress the bow and raise the stern, for that causes the cigar of lead on the fin to be drawn obliquely through the water instead of in a true fore-and-aft line, as it should.

A common error in designing a fin keel is in trying to add to the stability of the hull by making the hull flat. This is like taking two different doctor's medicines at the same time with the argument that if one can cure you in two weeks, two can do so in one.

The result is usually a failure, just as the fin-keel boat that tries to get stability from two conflicting sources. The hull should be round and full-sided, with freeboard enough to float the hull when heeled at about 30 degrees, so the deck edge does not crowd under water.

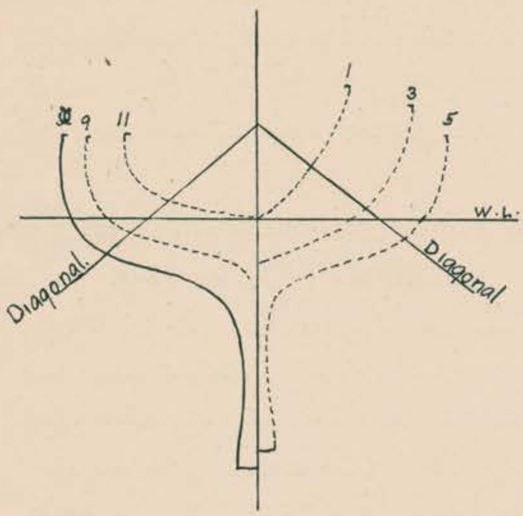
The slab keel boat has this disadvantage; the fin, being of wooden construction, is many times more cumbersome than the metal fin; this in itself destroys much of the good qualities of the lead on its lower edge. It is always trying to float to the surface which, is just what you don't want it to do. And it is so bulky it takes much more power to push it through the water.

Structurally the slab keel is a weaker construction than the S-shaped true keel. We are speaking, of course, of keels where the slab is quite deep, as it would be if the lead was as low as on the true keel or fin keel boat.

The old type of V-shaped cutters are now almost a thing of the past, for which we, in America, may be thankful. Such boats may be useful enough in British waters, where the sea gets up short and steep and yachts have to stay out and take weather that taxes large ships. The deep submerged body makes a steady craft in troubled waters, but it takes tons of ballast to make them stand up, without which they would flop over on their side.

And as to speed, they are compared with modern boats extremely slow.

You can, by now, probably decide the shape you want your midship section to be. The shape of this section gives you one spot to guide you in drawing the water line. - the width at section seven. With this width transferred to the half-breadth plan sketch in a shape for your water-line. Then you will have three spots to guide you in drawing all the other sections. You have the sheer spots, the water-line spots and the keel spots.

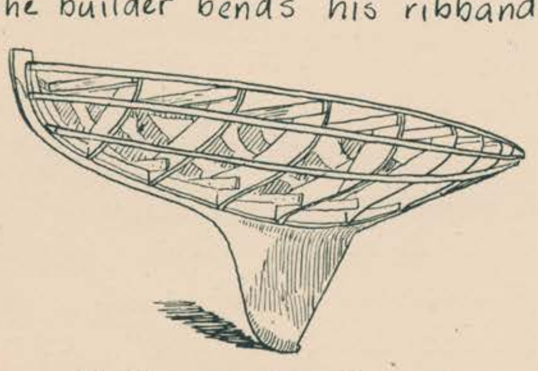


You will save lots of time and trouble now by sketching in lightly the purposed shapes of sections, number three and nine, one and eleven, and five.

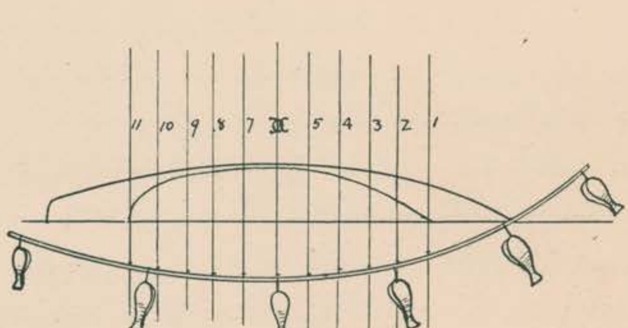
Then draw a diagonal line through the sections as shown in opposite sketch.

When sketching these shapes it may help you to bear in mind the idea that the builder does just what you are now doing. He cuts out temporary shapes or moulds, as they are called, just as you have now sketched in temporary sections in pencil. If their shape suits his eye, if his judgment can find no unfavorable criticism he proceeds to see if they are "fair," so that when he goes to bend the planking around it will touch fair on all the moulds.

This is what you must now do, and the quickest and most accurate way of doing it is to bend a batten around the sections just as the builder bends his ribbands.



Moulds and ribbands in place.



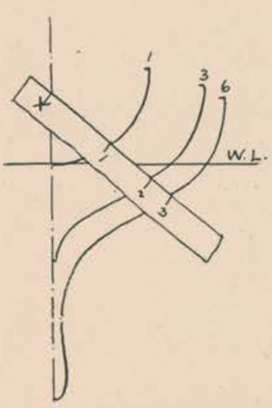
A batten bent to draw a diagonal.

Diagonals.

On the plans these battens are called diagonals, because they run in a diagonal line across the square lines already drawn.

The advantages of this are that they cross the sections at nearly right angles, instead of a very acute angle, as the water lines and buttock lines do on some of the sections where the exact point of intersection is hard to determine, and may vary any wheres from A to B, as shown in diagram.

The quickest way of taking off the measurements is to lay a strip of paper so one edge is along the diagonal to be faired and mark where each section crosses it, also where the cente line crosses. Transfer these measurements to their corresponding sections in the lower half of the half-breadth plan, Keeping the center line marked X on the center line in the half-breadth plan. This will give you a series of spots through which a batten should bend fair, touching each point.



To find where these diagonals end, measure the heigh from the base line up to where the diagonal crosses the center line in the section plan and transfer this height to the sheer plan to see how far forward on the stem and aft on the stern such a height will cross the outline of the hull in the sheer plan. These distances forward of section one and aft of eleven when transferred to the half-breadth locate the endings of the diagonals.

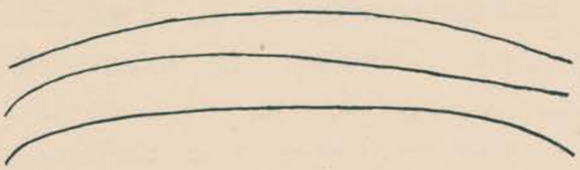
If the batten does not bend in a true, fair curve it shows that if the frames were put up that way the planking would not touch all the frames and "shims" would have to be put in, which is an undesirable practice.

But to you it shows that your judgment in sketching in the approximate sections was at fault. So change the sections that are unfair at the diagonal as the batten shows it. Don't force the batten into unfair curves to make the line go through the spots, but alter the spots.

On the other hand, don't make the common error most amateurs fall into of allowing the batten to decide the design for you.

The batten naturally will bend so as to make every line tend to a spindle shape in water-lines, buttocks and diagonals. Fix a shape of your ideal boat in your imagination and draw it by the use of battens, but don't allow the batten to alter your ideal.

Battens tapered from one end, from the middle toward each end, and of parallel shape throughout, will come in useful in various places to draw the required shape. For instance, it is difficult to make a parallel shaped batten bend in anything else but an arc of a circle, while a batten tapered from one end produces the parabolic curve and one tapered each way from the middle produces an elliptical segment.

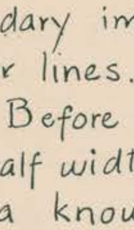


Arc
Parabolic
Elliptical

When the sections that the diagonal show are unfair have been altered to agree with the diagonal, you have another part of the plan faired up. By the use of intermediate diagonals all the sections can be made absolutely fair. Then to make the plan complete, although they are of secondary importance, as fairing up lines, draw in all the buttock and water lines.

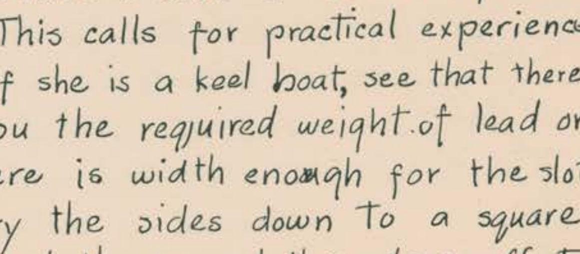
Before you finish the keel you will have to draw a line to represent the half widths on the bottom of it. This calls for practical experience and a knowledge of construction. If she is a keel boat, see that there is area enough in the keel to give you the required weight of lead or iron. If a center-board boat, see that there is width enough for the slot.

When you first draw the keel carry the sides down to a square edge to make it easier to fair up by and then round the edges off to suit your own ideas afterwards.



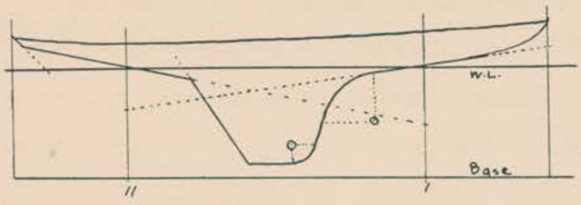
If the lead keel be a short bulb shape, draw enough intermediate sections to accurately show its shape.

In drawing a plan always bear in mind that the whole purpose of the design is to be a clear guide for some one else to reproduce full size, so it may be built from.



Plan of Lead Keel.

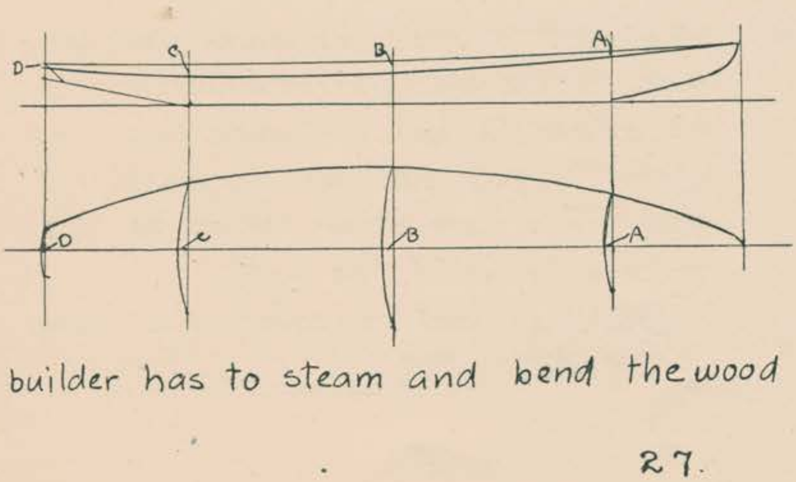
Give enough lines so the boat builder can see how you produced your curves. The straight line indicating the rudder post, for instance, carry it up to some main line, such as the water line and down to the base line, giving the measurements to these spots from some section. If any curves are swept with a compass give measurements, indicating the point it was swept from. Remember, the plan is something to be made use of, and not an ink drawing to hang on the wall in a frame.



The transom is one of the most difficult parts of a design to draw. To show its true shape requires considerable projection, More than even the average boat builder is capable of. It is easy enough to draw the shape of the mould just forward of the transom, but the transom being cut under on a bevel and having a curved face, as most of them do, make it very difficult.

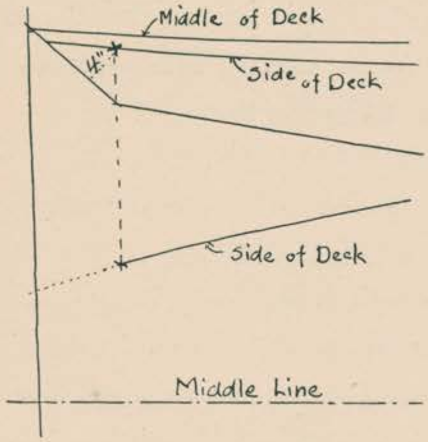
To project a curved face transom, draw in buttock lines about every six inches apart, from section eleven aft. you already have them drawn every twelve inches apart.

Then decide on how much crown or arch you want your deck to have, a half inch to every foot of beam is usual in small yachts. and draw this curve or "beam mould" as boat builders call it, across the half-breadth plan from side to side, spanning the full width of the boat at each section - this will give you the amount of arch or crown the deck will have at each section. Measure these distances above your sheer line and draw a line that will indicate the middle height of the deck, as at A, B, C and D.

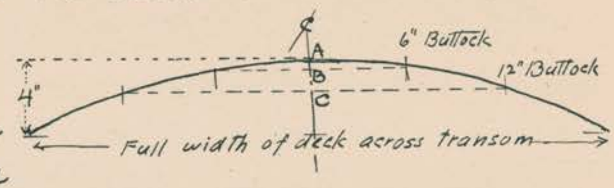


Then decide how much of a bend you want the face of the transom to have, remembering that if the transom is to be built up, as it will be if it has much depth, and not carved out of solid wood, That the boat-builder has to steam and bend the wood to give it the curve you want.

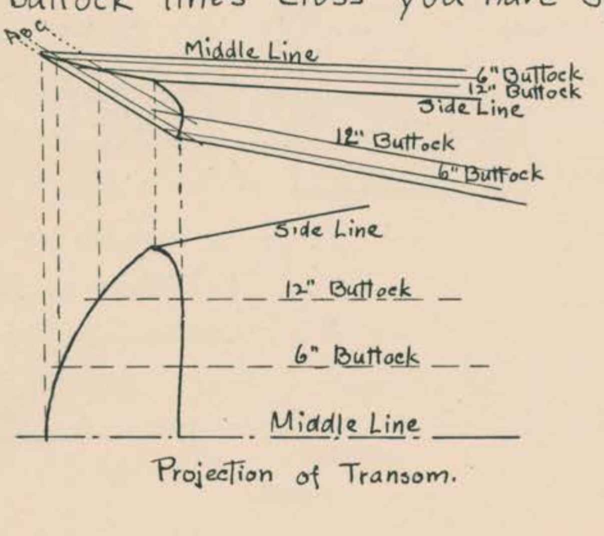
If you want three, four or six inches of curve, measure that distance up square from the face of the transom to where it crosses the side line; that will give you the ending for the side line of the boat.



To find the spots to draw the rest of the stern by you must carry the buttock lines up on the transom and along the deck. So mark out a curve similar to the face of the transom; if you decide on four inches, draw an arc of a circle that curves up four inches in the full width across the deck at the transom-



Each side of the middle line on this arc measure off the distance the buttock lines are away from the middle, and these distances, A to B and, A to C, will give you the distance the transom has curved up from the middle line on those buttock lines. Do the same with the deck curve and find out how much the deck drops 6 inches out, 12 inches out, etc. By measuring these distances up from the face of the transom and down from the middle of the deck you can draw parallel lines, those distances away, and where the deck and transom lines meet you have spots to show you how to draw the curve indicating the deck edge, and where the transom and buttock lines cross you have spots for the knuckle line.



Projection of Transom.

When the yacht's lines are all drawn, rule off a sheet of paper on which you can mark all the measurements necessary for the builder to have to reproduce those plans to full size on his mould loft floor. This he must do before he can proceed to build the boat.

Such a sheet is called the "Table of Offsets."

TABLE OF OFFSETS

FOR

32-FOOT WATER LINE SLOOP "MONSOON."

Designed for Mr. F. D. M. Strachan — Brunswick, Ga

By Mr. Charles G. Davis, N.A. — New Rochelle, N.Y.

August - 1899.

Heights to.-	Stem	1	2	3	4	5	6	7	8	9	10	11	12	Knuckle	Tip.
Under side planksh.r	8-6^{9}	8-0^{4}	7-7^{3}	7-3^{0}	6-11^{2}	6-8^{2}	6-6^{0}	6-4^{2}	6-3^{0}	6-2^{3}	6-2^{7}	6-4^{3}	6-7^{3}	6-9^{0}	7-0^{3}
Under side deck at center	8-6^{0}	8-1^{2}	7-9^{7}	7-7^{0}	7-4^{6}	7-2^{6}	7-0^{5}	6-10^{7}	6-9^{4}	6-8^{5}	6-8^{1}	6-8^{4}	6-10^{3}		7-0^{3}
Under side wood keel		4-11^{6}	4-0	3-1^{4}	2-3^{7}	1-8^{3}	1-3^{6}	1-1^{1}	1-0^{2}	1-0	1-0				
Rabbet		5-0^{5}	4-0^{2}	3-1^{4}	2-3^{7}	1-8^{3}	1-4^{0}	1-3^{5}	1-8^{5}	2-8^{0}	4-0	4-10	5-7^{7}		
Bottom of iron keel				2-10^{2}	1-9^{4}	1-0^{1}	0-6^{2}	0-2^{3}	0-1^{3}	0-2^{1}	0-5^{0}				
Buttock # 1		5-8^{5}	4-3^{3}	3-4^{0}	2-6^{3}	1-11^{0}	1-6^{5}	1-6^{7}	2-0^{6}	3-0^{3}	4-2^{0}	5-0	5-9^{4}		
" 2		7-4^{4}	4-7^{4}	3-6^{6}	2-9^{0}	2-1^{6}	1-9^{6}	1-10^{2}	2-4^{6}	3-3^{1}	4-3^{1}	5-1^{0}	5-10^{3}		
" 3			5-3^{1}	3-10^{4}	3-0^{1}	2-4^{7}	2-1^{1}	2-1^{5}	2-7^{7}	3-5^{6}	4-4^{4}	5-2^{1}	5-11^{4}		
" 4				4-4^{4}	3-4^{4}	2-8^{7}	2-4^{7}	2-5^{3}	2-11^{5}	3-8^{5}	4-6^{3}	5-4^{1}	6-3^{0}		
Half Breadths at-															
Planksheer		2-1^{3}	3-10^{4}	5-2^{2}	6-0^{5}	6-7^{0}	6-10^{2}	6-11^{0}	6-9^{6}	6-6^{2}	6-0	5-3^{1}	4-4^{0}	3-11^{6}	
Siding of wood keel		0-2^{4}	0-2^{6}	0-3^{6}	0-4^{7}	0-5^{6}	0-6^{0}	0-5^{6}	0-4^{6}	0-3^{1}	0-2^{4}	0-2^{4}	0-2^{4}		
W.L. # 9		1-3^{2}	3-7^{1}	5-1^{3}	6-0^{5}	6-7^{4}	6-10^{7}	6-11^{1}	6-9^{5}	6-6^{0}	5-11^{5}	5-1^{3}	3-2^{4}		
" 8		0-8^{6}	3-3^{0}	4-11^{3}	5-11^{4}	6-7^{0}	6-10^{7}	6-10^{7}	6-9^{3}	6-5^{2}	5-9^{3}	4-5^{0}			
" 7			2-8^{3}	4-7^{7}	5-6^{3}	6-5^{6}	6-9^{7}	6-9^{7}	6-8^{2}	6-2^{7}	5-3^{6}	1-0			
" 6			1-7^{7}	4-1^{7}	5-0^{5}	6-3^{4}	6-8^{0}	6-8^{1}	6-6^{0}	5-10^{0}	3-9^{3}				
L.W.L				3-4^{2}	4-2^{6}	6-0	6-5^{1}	6-5^{1}	6-1^{4}	4-11^{4}					
" 4				1-8^{6}	2-10^{5}	5-3^{0}	5-11^{6}	6-0	5-4^{7}	3-0					
" 3					0-8^{5}	4-7^{1}	5-3^{6}	5-6^{0}	4-1^{2}	0-10^{4}					
" 2						3-3^{2}	4-3^{2}	4-0^{4}	2-5^{2}						
" 1						1-3^{2}	2-7^{4}	2-5^{5}	0-9						
Diagonal No. 1		2-1^{3}	3-11^{5}	5-5^{0}	6-4^{2}	6-11^{5}	7-3^{5}	7-3^{6}	7-2^{2}	6-10^{0}	6-2^{6}	5-4^{5}	4-3^{7}		
" 2		1-10^{7}	3-8^{0}	5-0^{4}	6-0^{2}	6-8^{4}	7-0^{6}	7-0^{6}	6-5^{4}	5-11^{7}	4-11^{6}	3-9^{6}	2-7^{5}		
" 3		1-6^{5}	3-0^{4}	4-2^{2}	5-0^{6}	5-8^{3}	6-0^{4}	5-11^{5}	5-5^{4}	4-6^{7}	3-6^{2}	2-6^{0}	1-6^{0}		
" 4		0-9^{2}	1-11^{5}	2-11^{4}	3-9^{1}	4-4^{3}	4-8^{3}	4-7^{7}	4-1^{6}	3-2^{6}	2-1^{1}	1-2^{0}			

Mould Stations are 4'-0" apart. Diagonal #1 cuts center line 7-9^{0} above; W.L #8 .... 6-2^{6} out.
Water Lines are 6" apart. Diagonal 2 " " " 7-3^{6} " ; W.L 4 .... 5-9^{0} "
Diagonal 3 " " " 6-10^{6} " ; W.L 2 .... 4-0^{0} "
Buttock Lines are 12" apart. Diagonal 4 " " " 6-0^{0} , W.L 1 .... 2-3^{3} "

THE CALCULATIONS.

The necessary calculations to be made to determine the centers of a boat from the plans are in themselves quite simple. But the judgment necessary to decide the relative positions of these centers so as to give the best results for the work the vessel is intended to do, can only be learned by experience

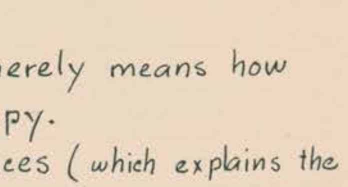
A few general rules may be cited; but, as you will later observe, the same results can sometimes be obtained by two extremely opposite types.

The center of buoyancy and displacement are figured from the same set of measurements. The center of lateral resistance from another, the center of effort from another, and so on. These names I know sound like so much Greek to those who need help at this stage of the game, and so I will explain them a little more explicitly.

Take first the calculation for displacement. This merely means how much space does the boat, from the water line down occupy.

When lowered into the water it pushes aside or displaces (which explains the term) a certain amount of water, and calculating displacement means to figure how many square feet of water is pushed aside by the baat.

It would be just the same were it a square box we were considering, and it may be easier for some people to comprehend when referring to a box; some get the idea into their head that because a boat is shaped into so many curved surfaces that there is some hidden science connected with it but there is not. The same principles that apply to a box on the water apply to the boat. The only difference is you can not figure out the number of square feet in the boat so easily as you can the box



A box 2 feet square if sunk a foot deep, would displace its size 2 × 2 × 1 = 4 sq. ft of water.

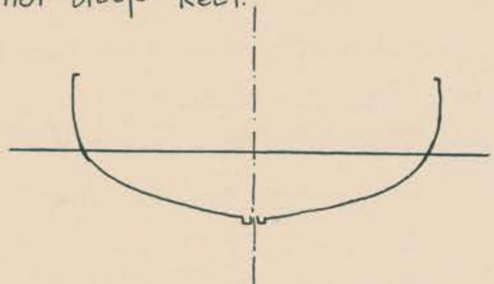
But a boat 20 feet long on the water-line 8 ft wide and 2 ft. deep would not displace what the product (20 × 8 × 2 = 320 sq. ft of water) which those figures give, because the boat is so shaped that more than half the bulk is cut away.

By actual figures, comparing two extreme types, we have

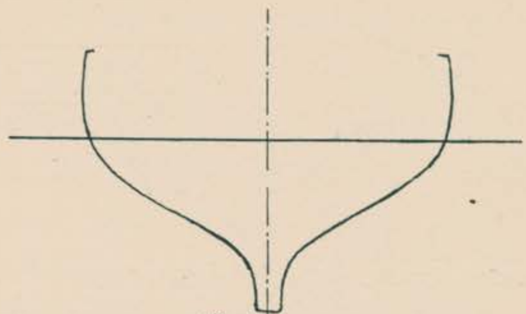
Alcatorda ... c.b. yawl ..... 35' w.l. × 14^{5}' beam × 3 draught = 1533 sq. ft.
Virginia ... keel schooner ... 46^{2}' w.l × 15' beam × 7^{5} draught = 5197 sq. ft.

Alcatorda's actual displacement was only 435 sq. ft., or 28% of 1533, the cubic feet contained in a block of her dimensions. She was an extremely full-bodied boat.

Virginia was much deeper. Her length x breadth x depth gave 5197 sq. ft., but she only occupied 12½% of this, or 645 sq. ft., on account of her deep keel.



Alcatorda



Virginia

Ships have a block coefficient, as this per centage is called, as high as 55 to 65%, but that is because their midship shape is almost a square box in shape and they are so very bluff-ended.

Yachts having sharper ends and deeper keels have less bulk.

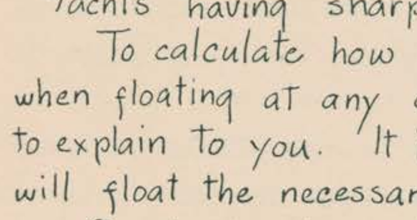
To calculate how much bulk or displacement a boat will have when floating at any desired depth on the model is what I am about to explain to you. It is very important to know this, to be sure she will float the necessary weights at her purposed water-line.

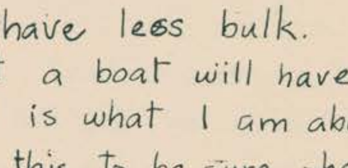
On the plan divide the water-line length into ten equal parts, this counting the ends gives you eleven lines or sections and ten spaces. Number the first line one, and so on to eleven. One being the forward end of the water-line and eleven aft. Section number six is the midship section.

If you know how to use a planimeter, and have one available, run it over the plan and compute the area of each half section as drawn in square feet. If not, draw enough small angles to enable you to figure the area by triangulation.

This is done as follows;- multiply the distance on line "a," Fig-1, by the combined lengths of lines "b" and "c"; this product will be twice the area of the half section.

Fig-1.





A planimeter.

So divide by 2, or leave it, as you would only have to multiply by 2 later.
Fig. 2. shows how you can equalize the "wine-glass" sections of keel boats into a triangle. Another way, Fig. 3, is to rule the section off into small squares and add them up; piecing the cut squares together to make up whole ones.

Fig - 2.

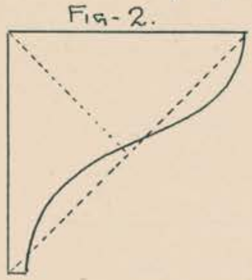
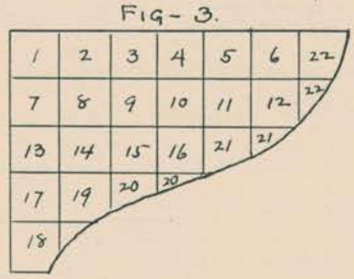


Fig - 3.



When you have figured the area of each half section write them in tabulated form as shown.
The whole secret of figuring displacement is contained in a rule, called Simpson's Rule, which reads as follows:- (amended so as to simplify it.)
Multiply the first area by 1, the second by 4, the third by 2; then alternately by 4, 2. 4. 2, etc., up to section 10; then section 11; the last section multiply by 1 again. Multiply the sum of these products by 2 to give you both sides of the boat, and also by the spacing between the sections, and divide by 3. The quotient will be the displacement in cubic feet. To get it in pounds multiply by 64 for salt water and by 62 for fresh water.

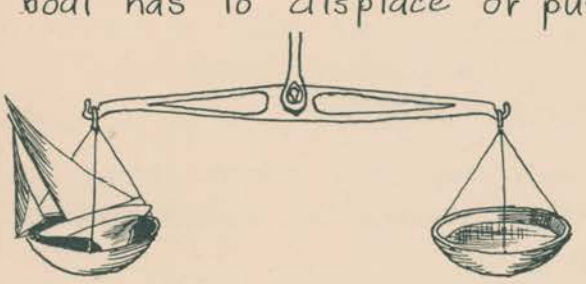
Section	Area	Simpson's Multipliers	Products		2d Products
1	0	1	0	5	0
2	5.	4	20.0	4	80.0
3	10.6	2	21.2	3	63.6
4	16.7	4	66.8	2	133.6
5	21.5	2	43.0	1	43.0
6	23.7	4	94.8	0	320.2
7	23.0	2	46.0	1	46.0
8	19.7	4	78.8	2	157.6
9	14.2	2	28.4	3	85.2
10	6.8	4	27.2	4	108.8
11	0	1	0	5	.0
			426.2		397.6

In the following table the areas as written are the areas of each section in sq. ft. as figured by planimeter, or by either of the other methods I have explained.
The sum of the products 426.2 is now multiplied by the spacing between the sections and divided by 3; to get the cubic feet in boat below the water-line.
If the spacing were 3.5 ft. multiply 426.2 by 3.5 and the product 1491.7 divided by 3 gives a quotient of 497.25 cubic feet displacement.
As the areas given represent both sides it is not necessary to double them.

To reduce this to tons divide by 35, as there are 35 cubic feet of salt water to a ton. To get it in pounds multiply by 64 for salt water and 62 for fresh.

$497.^{25} \div 35 = 14.^{20}$ *tons.* $497.^{25} \times 64 = 31824$ *lbs. displacement.*

If you fill a pan full to the brim with water and then place a model yacht into it some of that water has to over flow. If you catch what water runs out and put it in one side of a pair of scales and the model in the other side one will exactly balance the other, proving to those unfamiliar with such subjects that a boat has to displace or push aside her own weight in water.



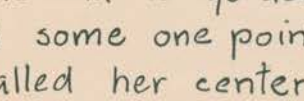
Or if you had a dry dock full of water and should launch a ship into it and measure the height the water rises you can easily figure her weight by multiplying the length by the breadth of the dock and the product by the height the water rose, and this by 64 or 62, according to whether it was salt or fresh water.

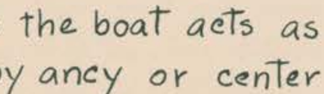
Supposing the ship didn't have her machinery in. you would find that as all this was put in place - boilers, engines, piping, etc., every thing in fact that was put aboard of her would sink her deeper into the water and cause the water in the dock to rise correspondingly higher - By measuring the water you could tell the weights of every thing going into the ship.

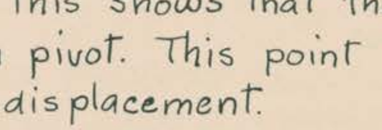
If you walk from one end of a boat to the other you cause one end to go down and the other to rise; this shows that there is some one point where the boat acts as on a pivot. This point is called her center of buoyancy or center of displacement.

You can find it by moving a heavy weight forward and aft along a boat's deck until both ends are depressed exactly the same.

But in designing you must be able to calculate this center long before the yacht is built, and be so sure of it that you can bolt on a heavy keel and have it sink her just right.







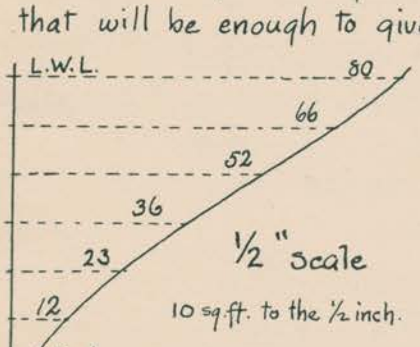
To calculate the position of the center of buoyancy, go back to the table on page 3. As section number six is the middle of the water line, start from there and multiply the products already obtained by 1, 2, 3, 4 and 5 as shown. Then add up all the second products from 1 to 5 in the bow sections and 7 to 11 in the after sections. The sum of the after sections is usually the larger. Subtract the smaller from the larger and divide the remainder by the sum of the first products. The result multiplied by the spacing shows how far the center of buoyancy is ford or aft of section six.

$397.6 - 320.2 = 77.4$ $\qquad 77.4 \div 426.2 = .181$

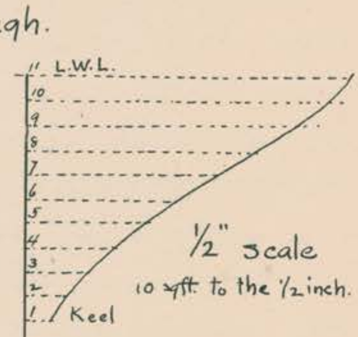
$.181 \times 3.5$ *spacing of sections* = .633 ft. the distance the center of buoyancy is aft of section number six.

To determine the vertical position of the center of buoyancy it is necessary to figure the area of each water line separately, and then draw a curve through a series of spots on the various water lines that represent the various areas. If the area of the load water line measures 80 sq. ft. mark a spot 8 inches out from the center line on a scale of ½ inch to the foot. This means every ½ inch represents 10 sq ft.

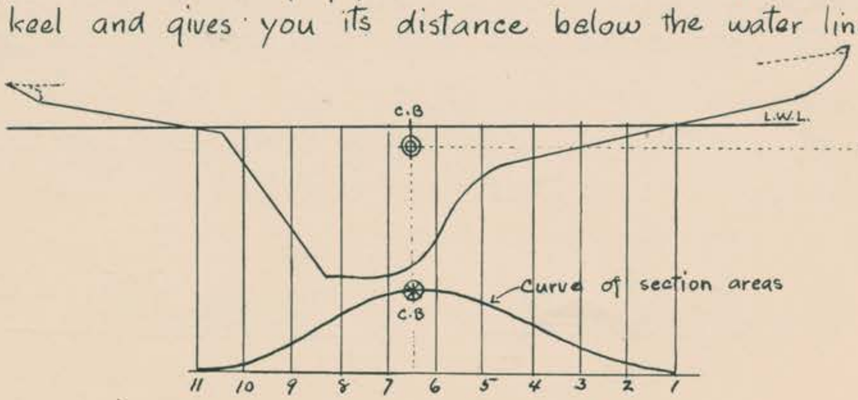
There may be only three, four or five water lines below the load water line, but that will be enough to give you spots to draw the curve through.

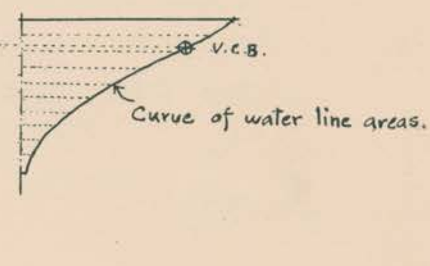


Then treat this curve as a new area. Divide it into Ten equal parts from the keel to the L.W.L. and measure the lengths of the ordinates of each spot so found on the ½ inch scale.



By Simpson's Rule you get the same number of cubic feet displacement as you had before, but the center of buoyancy instead of being figured in a fore-and-aft direction is now figured up from the keel and gives you its distance below the water line.






C
48