IC Hullform Development

Prior to the 1970 meeting of the ICF Sailing committee, the International Canoe Class allowed hullform development. In the preceeding hundred years, from the sailing canoe's inception in the 1870's, the flexibility in the canoe rules transformed the boat from sedate ketch rigged open paddling boats, to the challenging sloop rigged decked canoes we sail today. High watermarks along the way, in US Canoe sailing, were the adoption of the sliding seat (Paul Butler 1886), the sloop rig (Uffa Fox 1935), and the fully battened mainsail (1947). The era of the modern International Canoe really began in 1936 with Uffa Fox and his boat "Wake". In this article, I'm attempting to trace hullform development in the modern Canoe era, to see where we've come, what we've learned, and what direction this may point us in the future.

I make no pretense that this is a comprehensive survey and analysis of everything out there. Rather, it is the best I can do right now (with what I have in hand and self imposed deadlines for publishing looming over me). This reflects my current thinking (which may change tomorrow).

Enjoy.

Basics:

A boat moving through the water is essentially a volume process. Archimedes pointed out that floating objects displace a volume of water equal to their weight. Archimedes didn't plane, but even if he had, I don't anticipate that the dynamic lift associated with planing on a Canoe to exceed more than 30-40% of the displacement. Consequently, for much of our sailing, we are still faced with the problem of pushing ~390 lbs of water out of the way. If we pretend that water is "Play-Do" for a moment, we can shape our 390 lbs of water in a long skinny shape, or alternately into a short fat shape by changing the shape of the immersed portion of the hull. These changes impact the three major components that resist the hull slipping quickly through the water:

1) Wave resistance - the energy lost defying gravity i.e. creating waves that go on forever. Wave resistance is primarily a function of the longitudinal volume distribution and speed.
2) Frictional resistance - the energy lost in shearing the layer of water next to the hull. We can't do much about this other than sail hulls with less wetted area and make the hull as smooth as possible.
3) Viscous Pressure Drag - the catch-all for everything else that doesn't fit easily into the two previous categories, the chief component of which is associated with incomplete pressure recovery on the back of the hull. Although difficult to quantify, longitudinal curvature of the afterbody seems to be a big player.

What does an IC look like? We all (hopefully) know what an IC looks like in the flesh, but on paper hull lines may appear a bit odd, especially to the uninitiated. On the preceeding pages each of 12 hulls is shown from three different points of view: a side shot (profile view), looking straight down (plan view), and head on (body plan). The lines in each view are generated by intersecting an orthogonal grid with the hull. The curved lines in the bodyplan are transverse cuts of the hull at even foot increments, and appear straight in the other two views. Imagine pushing a canoe endwise through a monster food processor, then re-assembling the 1 ft wafers (a vivid imagination is a wonderful thing). Since boats are generally symmetrical port to starboard, the bow lines are shown on the right side of the bodyplan and the stern lines are shown on the left. Similarly the curved lines in the profile view are 2 inch wafers parallel to the centerline, and the curved lines in the plan view are 1 inch waterline slices below the waterline and 2 inches above. Other terms of interest are:

Rocker - the longitudinal curvature along the keel of the boat.

Deadrise - the wedge angle between the bottom of the boat and a horizontal transverse line.

Prismatic Coefficient - (CP) a measure of the fullness of the underwater ends of the boat. A high CP means that the volume is pushed towards the ends while a low prismatic coefficient indicates that the volume is clumped in the center.

Boats:

Five years ago I did a hydrostatic (hullform shape) analysis on most of the current modern ICs and NCs, from which I postulated a number of insightful trends and brilliant theories. Having finally gotten around to analyzing a half dozen of the earlier modern boats, I found my insightful trends and theories overwhelmed by the scatter. So, rather than bore you with numbers (I'll do that later) I've included the designer's comments (if available), and some of my own, for each of the boats. Then we'll do the numbers, talk about some characteristic design traits, and take a look where I think the class is headed.

Wake:

The comments of Uffa Fox from Sail and Power (1937)

"The plans of Wake show the fastest canoe ever yet designed or built, for on all points of sailing Wake could outsail our own boats, while she was able to defeat the Canadian challenger, even in the light weather that prevailed for the series. This was the only type of weather in which the challenger stood a chance at all, for like most American canoes, she had to be held upright once her mast was stepped to save her from capsizing, whereas our canoes come in, pick up their moorings, and their crews stand and walk about on their decks quite happily, this alone giving some idea of the ability of the two different canoes in a breeze of wind."

"The lines of Wake show that she is a development of Gallant. Actually she is the fourth of a series of lines, Solitary Snipe being the first, Gallant the second, Radiant the third, and Wake the final development of one hull."

Wake was undoubtedly a great boat, as evidenced by her racing success and the large number of boats built on both

sides of the Atlantic to this design. However, unlike Uffa suggests, I feel her superiority over American and Canadian boats was more a function of her superior sloop rig (compared to our cat ketches) rather than the wider stable hull. An IC derives its sail carrying power from its sliding seat, not the hull. Against modern boats, Wake would be outclassed, with too much volume in the ends to punch through chop, and too much wetted surface area in light going.

Whitman Deckboat:

Lou describes this boat as "similar to the Manana I except for the chine at the stern." Lou saved his best work for later. His Deckboat is fully 6" wider on the waterline than more modern boats with a commensurate stability and wetted surface area increase. To his credit, the bow above the waterline is narrow, a design trend he would regrettably later abandoned.

Sailfish:

The comments of Lou Whitman written on a drawing dated May 1942: "This canoe was built by me in 1942 and was the fastest reaching boat of all time. I was once clocked at 25 mph by a powerboat, however, it was never good enough to windward. It suffered from a poor centerboard (28" deep) and very bad sails which were homemade and had shrunk up to about 90 sqft."

Wow! Just when you thought you'd seen it all. As near as I can determine the bow really was less than 8 inches high, and must have relied heavily on the above waterline flare to keep it from going under. It is interesting to note that the deadrise angle of the bottom is carried all the way to the stern, a characteristic that would resurface on the Swedish chine boats in the early '70s and on Lust Puppet in '88.

Thais (Whitman Easy Build Single Chine):

Again the comments of Lou Whitman written on a drawing: "I built one of these for the NY Boat show that weighted only 102 lbs. That summer this canoe performed well and some of the boys wanted to make a one design out of it, against my wishes. Incidentally, the canoe would be a better decked canoe if the sheer were cut down to 11.5" amidships and 4" at the stern. It floated too high if turned over on its side, making it hard to bring up after a capsize. I was using a 0.25" thick aluminum centerboard, which was too flexible to stand on."

As recently as 8 years ago, Glenn Reynolds sailed a boat built to this design. I would hesitate to claim that he "campaigned" it seriously, so its performance is somewhat of a mystery. This is the only one of the older boats that I would consider owing/racing today. There are a number of good aspects to the hull design: it has fine ends, an even rocker distribution, and a bottom shape conducive to early planing. If the beam at the four inch waterline were pulled in to the minimum allowed under the National Canoe rule (32"), I think this design could pack some pretty impressive performance in an easily built boat.

Farrar 52:

As late as 16 years after Wake hit the water, it was still inspiring clones. Austin Farrar is responsible for this knock-off, which in character is nearly identical to Wake. Taking the conservative approach, Austin put Wake on a diet, trimming 2 inches off the waterline with a commensurate decrease in wetted area. This doubtless improved its performance, but the design remains more backward looking than forward looking.

Marchaj Mystery Boat:

This design appeared in the C. A. Marchaj's compendium Aero-Hydrodynamics of Sailing along with tow tank resistance data. For the longest time I believed it to be Wake, as I understood Wake to have been tank tested and the design exhibits a number of traits which are characteristic to Uffa: a "V"ed forebody, the rocker pushed forward in the boat, and a straight run aft with flat sections. If pressed, I would guess this boat to be a Procter design, as both the Avalon Procter and the Chippendale Procter had the same forward cant to the stern post, and more "V"ed sections forward than a Nethercott.

Whitman Manana II:

To my eye, the Manana II is an amazingly modern looking boat, given that it was designed in 1954 (give or take a couple of years). So enamored with the design was I, that I tracked down an old Manana to rebuild for the '93 Worlds, in hopes of showing the rest of the world just how far they had come in the area of hull design in the intervening half century. I came in 19th, and was dogmeat going uphill in the San Francisco Bay chop, so perhaps the answer is we have come farther than I thought. In the more moderate conditions of the Chesapeake Bay the Manana II is on par with the more modern boats, and not infrequently shows them her heels off wind.

The features that attracted me to the Manana were its narrow hull, low wetted surface, even rocker distribution, and easy midship section. On the down side, Lou had started incorporating hollows in the waterline at the bow, with fuller sections up above the waterline, both of which I believe are bad. The lack of a chine at the stern should probably also be categorized as a negative. Although the Manana doesn't really seem to miss the chine, I'm hard pressed to think of any other high speed hullform that doesn't have a transom of some sort. Why I hesitate to really come down on the stern design, is that the suction created by the rounded stern, coupled with the even rocker distribution, causes the Manana to sit back on her haunches (i.e., trim bow up, stern down) on a planing broad reach. I have never sailed a canoe before that, when on an off-the-end-of-the-seat broad reach, you can look down and see 9 inches of daggerboard out of the water. If the only way you have ever gone downhill is with a snorkel and periodic green water over the foredeck, then I should tell you ... there is another way, and it's FUN!

Whitman Phoenix:

Lou Whitman designed the Phoenix to compete in the '66 (maybe '69) Worlds. He called it his "Old Man's Boat", recognizing that age had slowed him down a bit. He hoped that by making a wider, more forgiving IC, his boat handling would not handicap him relative to younger sailors in tippier craft. The Phoenix is the maximum width allowed in the NC rule (43"). In fact, the first Phoenix Lou built was 45" wide due to a construction mistake, which he corrected by creating a harder turn of the bilge amidships. The visual impact sailing a Phoenix for the first time is that of an aircraft carrier. There is boat everywhere you look ... This boat is wide, and it carries the width at the deck level well into the ends. Lou was clever about it though, by giving the hull a pronounced "V" shape he kept much of the boat out of the water, so the boat does not suffer a wetted surface penalty. Lou had a mold made of the boat (which Ted Causey now owns) and upwards of 20 Phoenixes have been made from the mold.

The characteristic of a Phoenix that elicits the most comments (aside from its width) is the transom. The chine line rakes up sharply to intersect the sheer line about 2 ft forward of the sternpost, creating a tiny triangular transom that most people seem to consider ugly. I might too, except I have seen it work. This transom configuration allows the boat to be sailed heeled (which admit it or not, most of us do) without incurring the drag associated with digging the outboard edge of the transom in the water. Look at the wake of your Nethercott sometime and notice just how flat you have to keep it to prevent that nasty roller from forming off the chine. Phoenixes don't do that.

Ames/Mincher Multi-Chine:

The Ames/Mincher multi-chine boat was a collaborative effort between naval architect Bob Ames and Canoe sailor Rod Mincher to produce a "Nethercott equivalent" that could easily be home built. A chine hull design was pursued since plywood was the hull building material of choice. Since Bob thinks corners are slow, a multi-chine shape evolved to approximate a round bilge hullform. The result, according to John Williamson (who should know having built two boats to this design), is sufficient building complexity to daunt most home builders. The design has the Ames signature flat along the keel to promote early planing and an admirably narrow stern. Perhaps the biggest drawback of the design is the fullness of the first chine fully above the waterline at the bow, which was suggested by Rod as a cure for the nose-diving tendencies of a Nethercott. In hind sight, the full bow means punching a bigger hole through waves (which is generally considered to be a bad thing (unless you really like spray)), and fore and aft sliding seat carriages are a more effective means for preventing nose-dives. As for the goal of creating a Nethercott equivalent, the Ames/Mincher multi-chine boat appears to be that. Although the boats have never been in the hands of a top flight racing skipper, their performance seems to be on par with that of a Nethercott.

Lust Puppet:

Lust Puppet emerged from the desire to get Rod Mincher a new boat to replace his aging KFCC Nethercott. Since construction would fall largely on my shoulders, I elected to do the easiest thing I could think of - a single chine boat.

The design was inspired by the 3 Swedish single chine canoes that were built just prior to the adoption of the one-design rule in 1970. John Williamson published the lines to one of these boats in the Jun85 Canoesletter. I worked from these lines, tweaking here and there, to produce a boat that is probably narrower, particularly in the ends, than any of the original boats. The forward waterplane area of a Nethercott is maintained, but the flare above the waterline was entirely eliminated. This, coupled with an even rocker distribution and a narrow stern, produced a wicked fast boat. Lust Puppet's speed, however, comes at the price of stability. The boat is clearly more tender than a Nethercott. I attribute this to the transom design, which allows the boat to heel over substantially before immersing the chine. As a result, there is never a time that both chines are in the water at the same time. Smaller waterplane area -> less stability

This is the first design that I am aware of that is clearly faster than a Nethercott, as I think all who have sailed against it will agree.

NoGo55:

I find it unfortunate, but only Nethercotts (barring grandfathered boats) are recognized as International Canoes. To play on the international stage, you must play with a Nethercott. Since the building tolerances are fairly generous (a cascading +-10mm), I set about "playing" with the Nethercott lines so as to make my building errors in ways that would make the hydrodynamicist in me happy. The result was US-208 which Rod Mincher sailed to 42nd place in the '93 Worlds. The NoGo55 design differs from a standard Nethercott in the following areas:

1) The underwater bow sections are made as full and flat as possible, while the flare above the waterline is eliminated as much as possible.
2) The rocker is flattened and pushed back in the boat as much a possible.
3) The boat is as narrow as possible from amidships aft.
4) The chines are pulled out of the water as much as possible with more rounded sections at the stern than normal.
5) The underwater volume is pushed to the ends of the boat.

The result - it's still a Nethercott, but it seems to be a fast Nethercott.

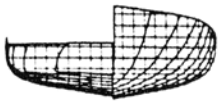
Nethercott:

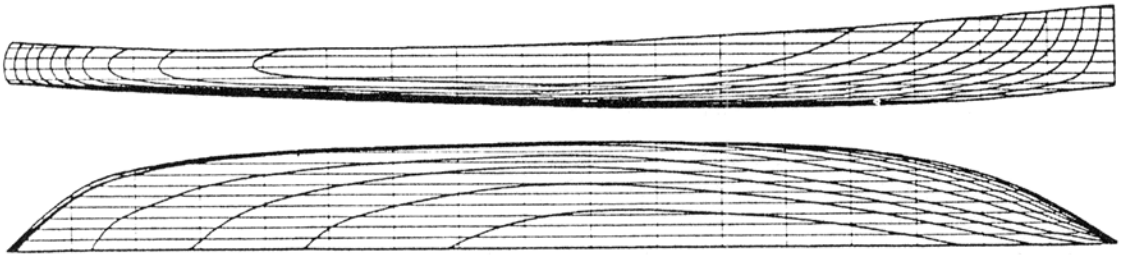
Before I sound too negative, I should say that a Nethercott is a good design, that has served the class well. But having said that, I think we can do better. The characteristics of a Nethercott that I take issue with are its intolerance to heel, and its sensitivity to weight placement. In light air you can't get too far forward to get the transom out, and in a breeze you can't get too far back to try to keep the bow from burying.

Marchaj Mystery Boat

Designer - Unknown

Max Beam	38.8 in	WS	34.11 sqft
WL Beam	36.2 in	CP	0.445
Draft	5.16 in		

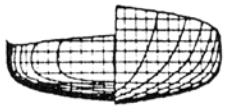


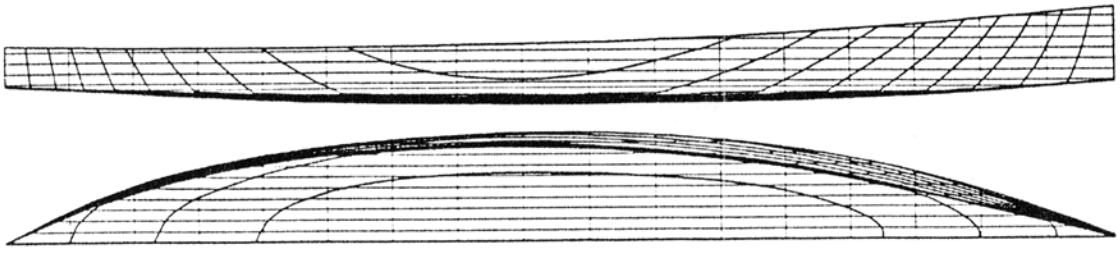


Farrar 52

Austin Farrar - 1952

Max Beam	39.6 in	WS	33.88 sqft
WL Beam	35.3 in	CP	0.499
Draft	4.37 in		

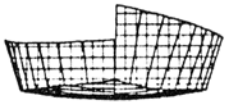


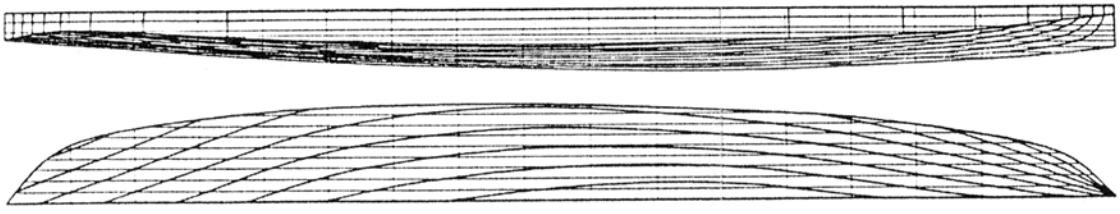


Thais (Whitman Easy Build)

Lou Whitman - 1946

Max Beam	39.9 in	WS	35.11 sqft
WL Beam	35.4 in	CP	0.473
Draft	3.58 in		

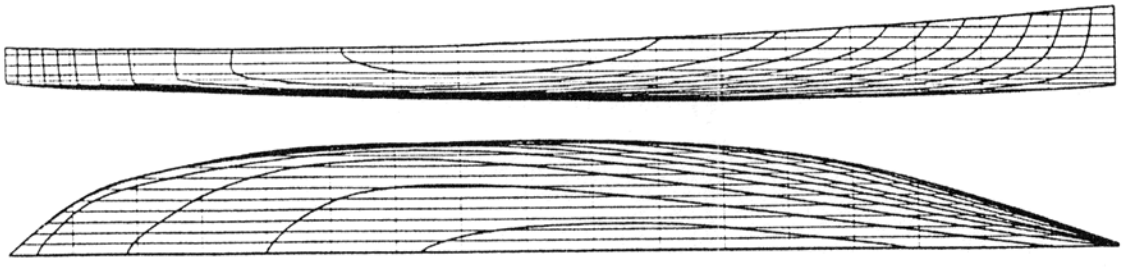




Sailfish

Lou Whitman - 1942

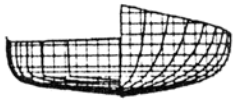
Max Beam	36.0 in	WS	33.28 sqft
WL Beam	36.0 in	CP	0.368
Draft	5.31 in		

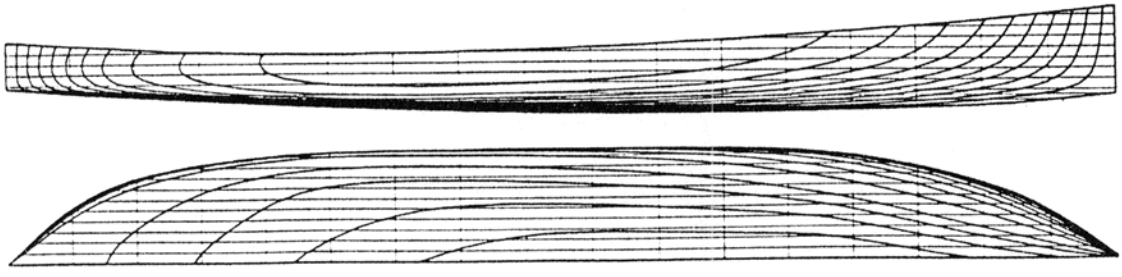


Whitman Deckboat

Lou Whitman - ~1940

Max Beam	41.3 in	WS	36.24 sqft
WL Beam	38.1 in	CP	0.529
Draft	3.98 in		

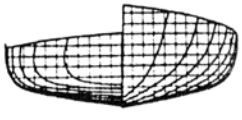




Wake

Uffa Fox - 1936

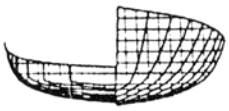
Max Beam	42.7 in	WS	35.32 sqft
WL Beam	37.2 in	CP	0.549
Draft	4.21 in		

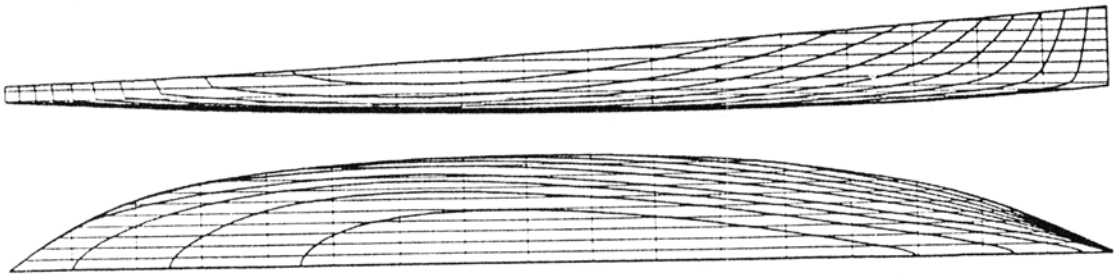


Nethercott (Standard IC)

Peter Nethercott - ~1969

Max Beam	39.9 in	WS	33.22 sqft
WL Beam	34.1 in	CP	0.510
Draft	4.52 in		

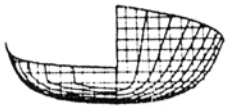


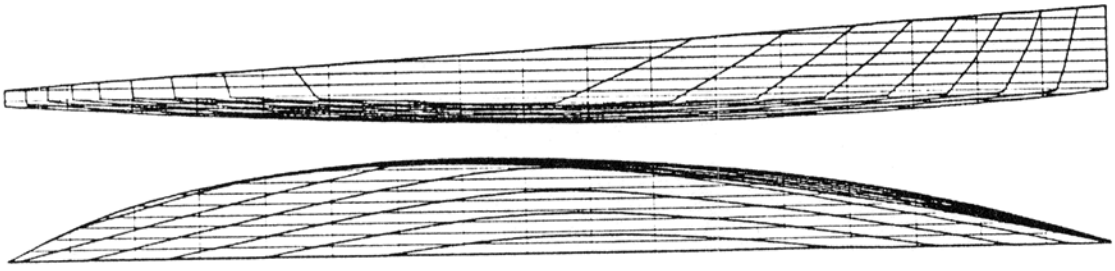


NoGo55 (Pushed Tolerance IC)

Bill Beaver - 1992

Max Beam	39.6 in	WS	32.13 sqft
WL Beam	32.8 in	CP	0.519
Draft	3.95 in		

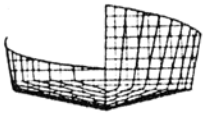


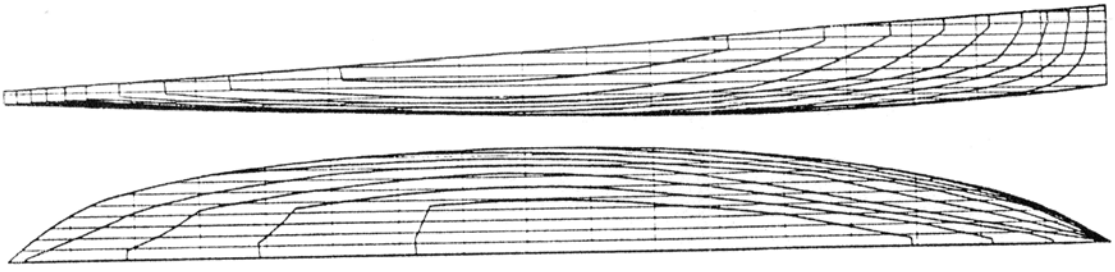


Lust Puppet (Single Chine NC)

Bill Beaver - 1988

Max Beam	39.6 in	WS	31.62 sqft
WL Beam	32.8 in	CP	0.466
Draft	3.95 in		

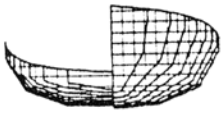


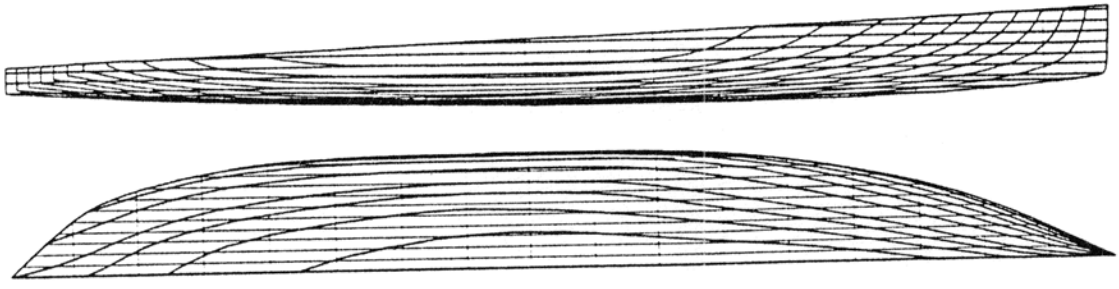


Ames Mincher Multi-Chine (N

Bob Ames & Rod Mincher - 1983

Max Beam	38.8 in	WS	31.56 sqft
WL Beam	32.5 in	CP	0.508
Draft	4.13 in		

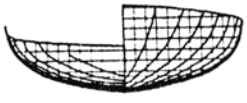


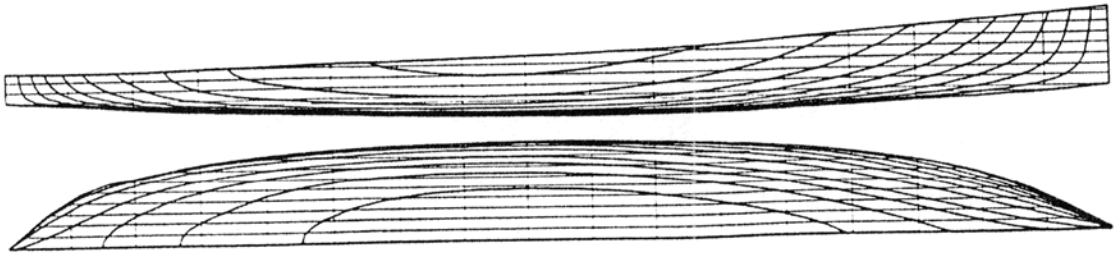


Phoenix (Grandfathered IC and NC)

Lou Whitman - ~1966

Max Beam	43.0 in	WS	31.52 sqft
WL Beam	33.2 in	CP	0.512
Draft	4.41 in		

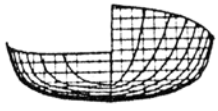




Manana II (Grandfathered IC)

Lou Whitman - 1954

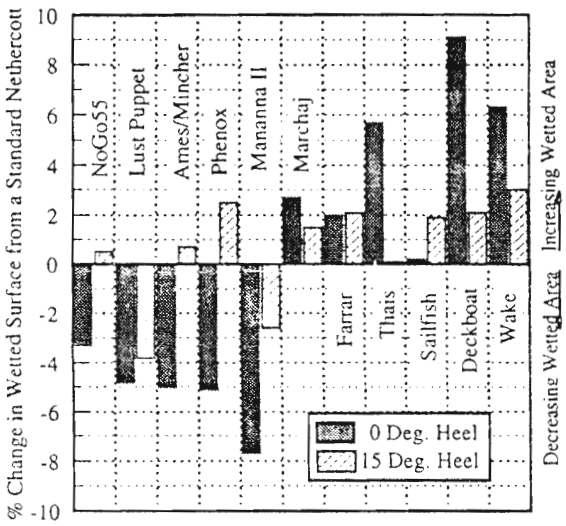
Max Beam	37.7 in	WS	30.68 sqft
WL Beam	32.0 in	CP	0.515
Draft	4.03 in		



Numbers:

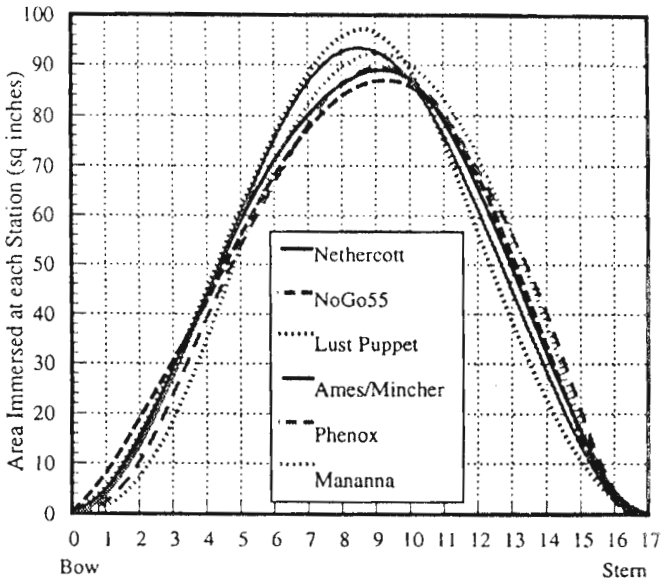
Naval architects love to harp on wetted surface, and , if you promise not to tell, I'll let you in on our dirty little secret ... The calm water wetted surface of a hull is about the only number we know with any certainty. How much drag does this hull have? Don't know. How much of that is due to a breaking bow wave? Don't know. What is the effect of straightening the rocker? Don't know. Ask me something I know - how much wetted surface a hull has? Wetted surface matters because at typical sailing speeds about half the drag (more at low speeds) is due to dragging wetted hull area through the water. Do you want to decrease your hull resistance by 2%? Easy, decrease your wetted surface by 4%.

In the graph below the wetted surface for each design is shown relative to that of a Nethercott for a displacement of 390 lbs. Obviously most of the older boats sailed at a higher displacement, (what with wood rather than carbon masts, weighted centerboards, etc.), but I think it is telling that all of the older, ostensibly slower designs, had more wetted surface area.

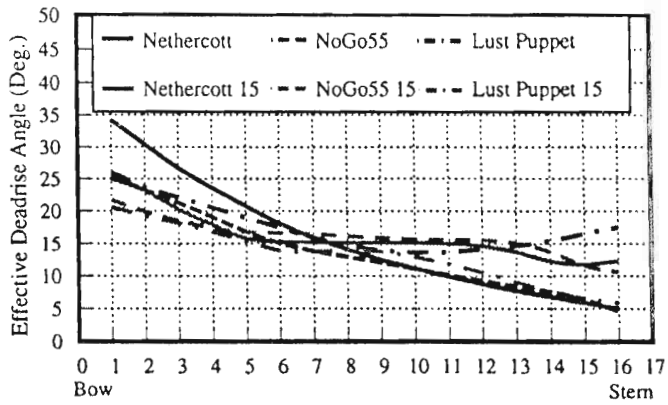


What this graph doesn't highlight is the reduction in wetted surface attributable to heeling. A Nethercott loses about 12% of its wetted area by heeling the hull to 15 degrees. Unfortunately, it also picks up drag by digging in the chine, as well as losing some efficiency in the rig and blades due to heeling. But think for a moment, what can happen for a boat like Lust Puppet, a Phoenix, or a Manana II that can be rolled without picking up extra transom drag. We're looking at anywhere from 10 to 16 percent less wetted hull area. Hmmm.

Another number we can calculate pretty well is the prismatic coefficient (CP), which provides a gage as to whether the volume is clumped in the center of the boat or spread out towards the ends. At speeds below 4 knots a hull with fine ends and a fat midship (optimum CP ~ 0.5) has less resistance. At speeds above 6 knots the situation is reversed, i.e., the volume should be pushed from the middle of the boat to the ends with an optimum CP of approximately 0.67. The astute observer will note that the prismatic coefficients listed with the lines drawings of the boats are no where near 0.68. Yep, with the design constraint of having a minimum of a 32 inch beam at the 4 inch waterline there is no way, without serious measurement bumps on the hull, to get rid of the volume amidships and really get the prismatic up. Still, we should do what we can, and that includes straightening the rocker, minimizing the midship section, and eliminating hollows in the forebody waterlines.



The last number I'd like to have a go at is the effective deadrise angle. Although "Deep Vs" are prominent on planing powerboats (where there is power to burn), if you want to plane on a budget you do it on a flat bottom. Effective deadrise angle measures how flat the bottom is. All else being equal, the lower the angle the more lift the section will generate. The following graph shows the effective deadrise angle for the two Nethercotts and Lust Puppet at two heel angles.



Worth noting is that it is only the sections experiencing a positive angle of attack that are generating lift. Thus, flat sections in the forebody are more advantageous than flat sections in the afterbody, unless you can stand the boat on its stern. A standard Nethercott is flat where it doesn't need to be and V'ed where it does. Also striking is how, when laid over on a chine, Lust Puppet "becomes" a narrow flat bottomed boat.