

Super Fuel Efficient Long Range Motoryachts

This paper is a follow-up to our work published in a **SNAME 2000** paper "**Development of a 47-foot Modern Trawler Yacht**". In that paper I discussed the work we had done to date and its application in a small ocean-going yacht. Since that time we have had the opportunity to expand on that work considerably as well as apply it to larger vessels both in retrofit and new build construction. For those who have not had the opportunity to read that paper and/or are not familiar with our work let me start anew.

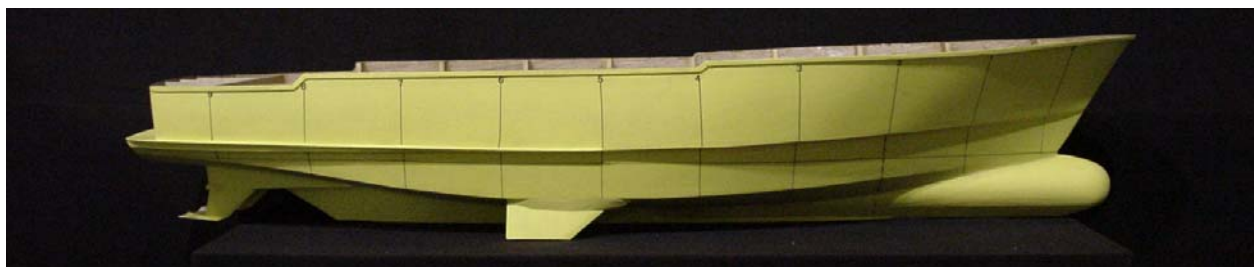
Over 14 years ago we started an in-house research project to increase the efficiency of long-range motoryachts. Our goal was a hull form that was efficient over a wide range of displacement and high semi-displacement speeds. The basic scenario was for a long-range motoryacht capable of serious ocean passages such as trans-Atlantic or better, at displacement speed, with a comfortable motion, good stability characteristics and with very good fuel economy. Once over to the Mediterranean or other local waters the vessel could power around at high semi-displacement speeds, in order to keep up with faster local yachts, while still maintaining the same high degree of comfort and fuel efficiency, then return across the Atlantic in a displacement mode. To do this we were not looking to re-invent or re-write Naval Architecture but instead to refine it by utilizing and enhancing the technology that currently exists. The analogy I like to use is that of the internal combustion engine, from the first inefficient version to its modern-day efficiency. One of the first engines (1890) was a 1.1 litre motor capable of 4 hp @ 900 rpm (Daimler/Maybach). Today that same size motor with today's efficient carburetors, turbo chargers, header exhaust, fuel injection, and careful intake and exhaust porting can develop 68 hp @ 6000 rpm while still being lighter and more fuel efficient than the original model. The basic principles of combustion and even the general design of these motors have not changed from the initial concept but fine-tuning the design has brought huge gains. Much of this has been brought about by bolting on better carburetors, tuned air intake and exhaust systems, etc. In the same spirit we evaluated the principles of a good basic hull design and then looked at increasing efficiency by utilizing enhanced "bolt-on" appendages.

Market Response:

The only reason any of this work is even made possible is the huge and ever growing interest in long-range motoryachts, also known as passagemakers. As aging baby-boomers retire with a record amount of wealth, in good health and with a thirst for adventure, they look to the capabilities of the fishing trawlers and crabbers and ask if it is possible to achieve that seaworthiness in a yacht. The commercial fleets, the majority at 60-90 ft., head out to sea off the coast of Alaska and Canada in some of the worst weather imaginable, to do what one TV documentary called "The Most Dangerous Job In The World". These single-screw displacement vessels venture many miles out into open ocean year after year. Many have been converted to pleasure craft, some with more success than others. The baby-boomers with their high-tech interests are intrigued by, and look for, innovation - as long as it is backed up by solid engineering. Many have earned their retirement funds from the dot-com industry and see innovation as a part of their everyday life.

Hull Design:

Our hull design work started with a paper study on various published hull forms, their relative efficiencies and seaworthiness. We looked at standard resistance curves for displacement, semi-displacement, and planing hulls to establish their "sweet spots" and how they applied to the speed/length ratios that we had targeted. Out of this analysis came the affirmation of a long-standing belief that a lobster boat type of hull is by far the most efficient over this range of speed ($\sqrt{LWL} * 0.9 - 2.3$).



From here we mixed and matched a variety of features to solve shortcomings and further enhance performance. We featured a fine bow for low resistance and low bow wave but high, wide spray knockers to add significant volume when pitching into a seaway. Low transom immersion reduces drag at low speeds and wide spray chines above the waterline give trim control at higher speeds.

We also drew on our own research adding to the available technology. From this work we have seen real gains in efficiency and have been able to incorporate these features into vessels without having to resort to unattractive styling or stealth-style lines. In fact, this contemporary styling makes these boats real sleepers, disguising their efficiency to the point that their abilities are often dis-believed even with reality floating right there at the dock.



Cape Scott 86 at 15 knots

At 6 knots with this hull shape, there is no noticeable wave train. At 15 knots there is considerably less wave than most moderate-displacement trawlers. At 20 knots, this form is equal to chined, fully planing forms for resistance and wave profile.

Appendages:

Bulbous Bow:

Our bulb design work was inspired by the work of Dr. Calisal from the University of British Columbia who did extensive studies on the application of bulbous bows on fish boats in the early nineteen eighties. From his published work with the fishing vessel "Kynok" we have refined his concepts, developing our own technology that results in a bulb design that is effective from 8-20 knots and producing a drop in resistance of over 13% at it's maximum efficiency. In retrofitting bulbs to over 36 existing vessels we have found that the attachment of a bulb will produce an immediate $\frac{3}{4}$ knot increase in speed, or the equivalent fuel savings. A quote from a recent model-test program for an 86-footer states *"From the Resistance and EHP plots it is evident that the bulb reduces the required power throughout the range of speeds from 9 to 19 knots, with crossover at 20 knots. The reduction is accomplished through wave cancellation and by reduction of the running trim due to the hydrodynamic forces acting on the bulb."* In addition to these fuel savings there is close to 50% reduction in pitching motion - but more on that once we have discussed some of the other appendages.

Bi-foil Skeg:

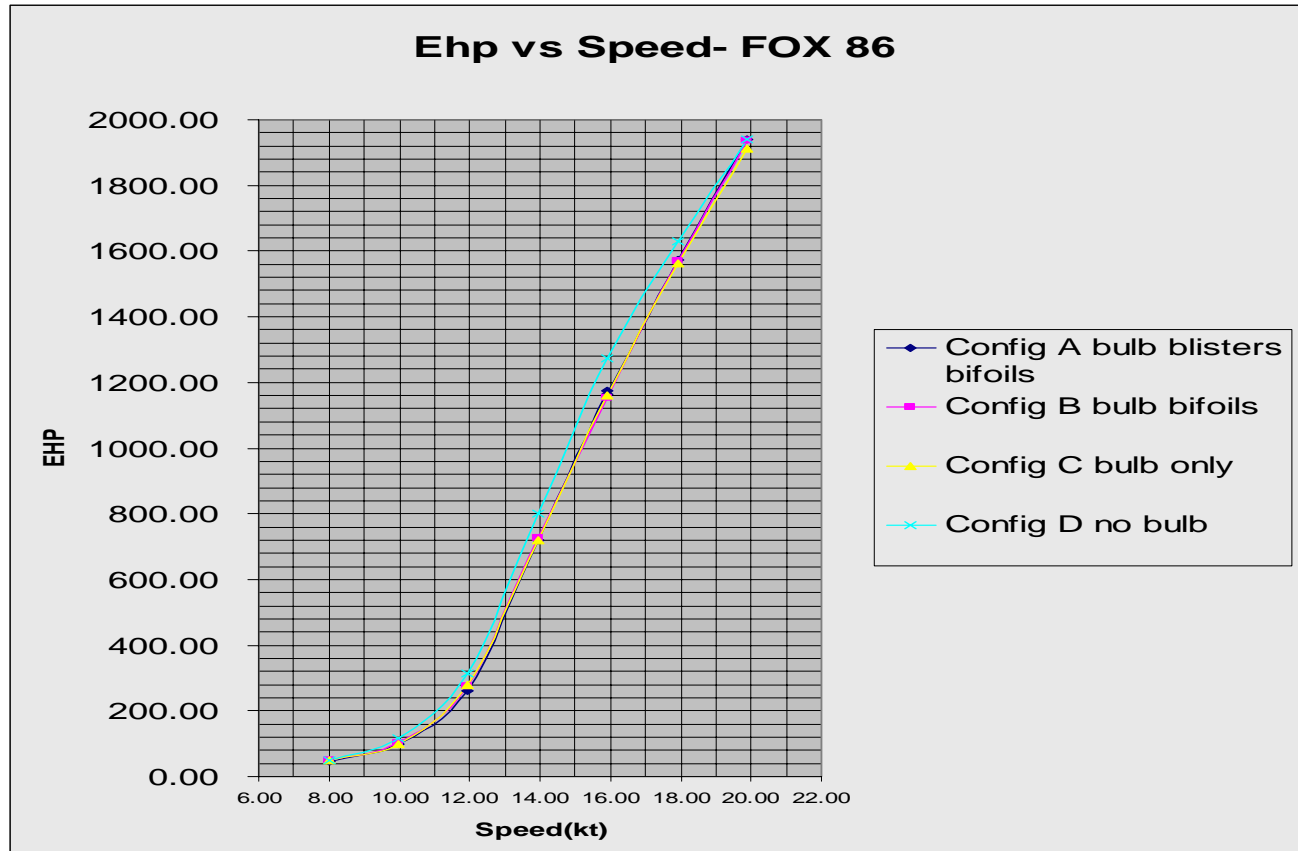
Another piece of technology inspired by work developed for the fishing fleets is our "Bi-foil Skeg". It's evolution is a paper in itself but suffice it to say that it came about through drag reduction technology applied to the net guard, typically called a "Beaver Tail", fitted under the propeller on fishing seiners. By

optimizing the plan form and utilising a proper hydrodynamic foil section it is possible to increase propeller thrust while reducing pitching motions at the stern and providing protection for the propeller.

Midship Blisters:

Our most recent advancement comes through the use of significant appendage fairings. Having reduced the bow wave with a fine entrance angle and the use of a bow bulb we turned our attention to reducing the midship hollow. It was reasoned that this would help reduce drag by reducing the overall wave train and increase stability underway by reducing the midship hollow. Essentially we are trying to duplicate the success of the bow bulb with a midship bulb or bilge blister. Although this technology is still very new we have achieved a maximum reduction of 6% drop in resistance over a range of speed from 8-16 knots with no resistance penalty on up to 20 knots.

Powering predictions:



Comparison to a typical trawler:

On comparing our powering estimates to other existing vessels without this technology we find that our designs are 30% more efficient and will operate over a wider range of speed. This has been ocean-proven in long offshore passages. Lower fuel consumption means less fuel to carry to achieve long range. Less fuel means less weight to carry. Less weight means a smaller engine required and less structure weight to carry it. Which means less overall weight that requires less power to move and lower fuel consumption, etc. What is generally a vicious circle, (more fuel for greater range requiring more power that consumes the extra fuel), has become a spiral of benefits.



Typical trawler at 10 knots



Our trawler at 10 knots



Typical trawler at 13 knots



Our trawler at 13 knots

Performance figures of a typical trawler compared to our work:

Speed	SHP		GPH		Range		Gal/mile		%
	Typical	Ours	Typical	Ours	Typical	Ours	Typical	Ours	
8	100	108	4.0	4.2	13905	13568	0.50	0.52	-92.6
10	316	238	13.3	9.6	5279	7696	1.33	0.91	132.8
12	808	615	33.9	24.7	2476	3546	2.83	1.97	131.4
14	2266	1725	95.2	69.2	956	1476	7.4	4.74	131.3

Seakeeping:

The added appendages and slick hull form also give superior seakeeping characteristics. Not only can the vessel operate economically at a higher speed, but there is no loss in the degree of comfort. The reduced bow wave height means that when the bow enters a wave there is less water being pushed aside so there is less water to come on deck. In fact, clients tell us that this form produces a very dry boat overall.

Superior seakeeping - seakeeping data, bulb vs no bulb:

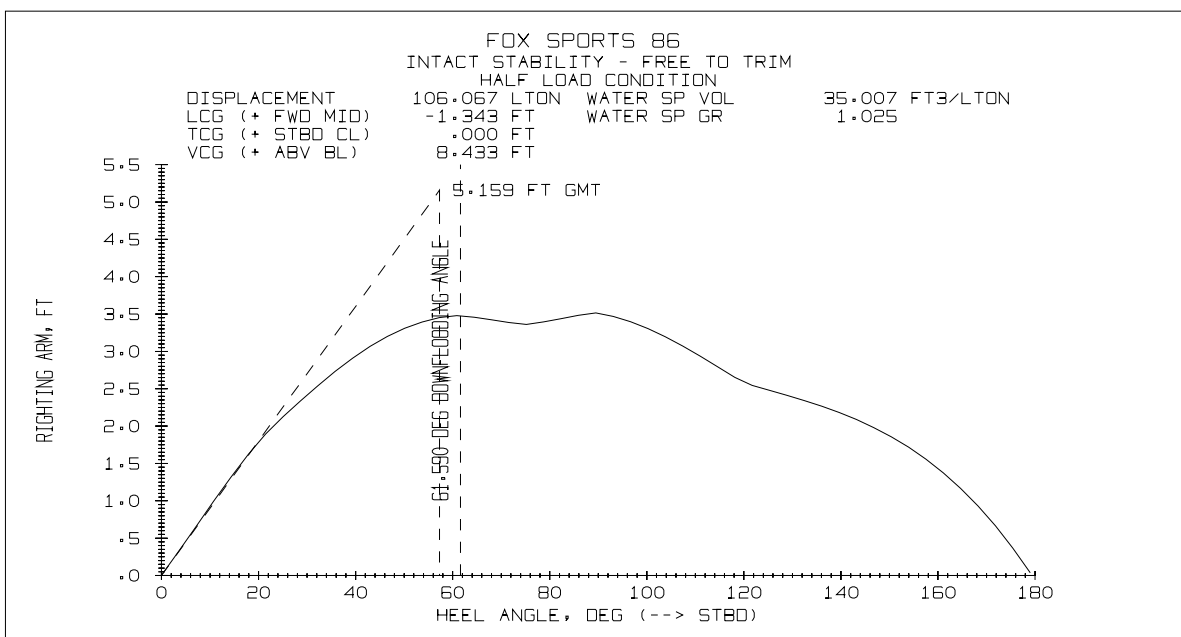
Seastate	Speed (kt)	Bow Accelerations (g - rms)	CG Accelerations (g- rms)	Stern Accelerations (g-rms)
Config D no bulb, no bifoil				
SS 3	8	0.247	0.091	0.124
SS 3	10	0.275	0.109	0.145
SS 3	12	0.273	0.115	0.159
SS 5	6	0.281	0.106	0.148
SS 5	8	0.349	0.138	0.185
SS 5	10	0.374	0.159	0.210
Config B bulb and bifoil				
SS 3	10	0.254	0.109	0.138
SS 3	12	0.256	0.122	0.154
SS 5	8	0.298	0.127	0.164
SS 5	10	0.352	0.160	0.200

It can be seen from this table that with the addition of the appendages the vessel has virtually the same degree of comfort at 10 knots in sea state 3 as it does at 8 knots in the same sea without the appendages. In fact, an increase in speed to 12 knots causes very little increase in pitching motions. This 2 knot speed advantages continues to be true at sea state 5 as well. The addition of the appendages allows a 2 knot increase in speed with no real increase in motions for the vessel. (Sea-state 3 is defined as having a scale significant wave height of 3.5 - 4.0 ft. with a scale significant wave period of 5.8 seconds. Sea-state 5 is defined as having a scale significant wave height of 8.0 – 12.0 ft. with a scale significant wave period of 8.25 seconds.)

Stability:

All of these other features would be for nothing if the hull form produced did not have stability characteristics in keeping with a good roll period in a seaway and with sufficient range of stability to make the vessel safe for long range ocean cruising. Fortunately, this hull handles that issue also, having not just stability to meet the minimum requirements of International Authorities but a good, healthy range of stability.

We have done extensive studies on stability parameters and the effects of hull and superstructure forms on the range of positive righting arm. Every effort is made to keep weight low in the design of the vessel and then as features are incorporated into the overall form they are placed and planned to produce a good overall movement of the center of buoyancy in relation to the center of gravity. The resultant vessel has excellent stability parameters without having to resort to anything more than trimming ballast.



Examples:

"Amnesia IV" was one of our first large fiberglass motoryachts to take advantage of some of this technology. It is 86 ft. long with a 23 ft. beam and 6 ft. of draft. With a single 1300 hp MAN diesel it achieved a top speed of 15 knots. At 210, 000 lbs. displacement (half load) it is considered to be a medium weight vessel. It has a 7000 mile range at 9 knots on 6000 US gallons of fuel. On a trip from Vancouver, B.C. to San Diego, CA the vessel easily averaged 9 knots in big seas and high winds burning less than a gallon per nautical mile, (including generator run time), in comfort.

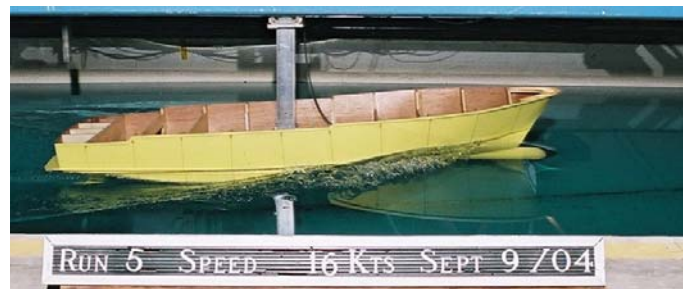
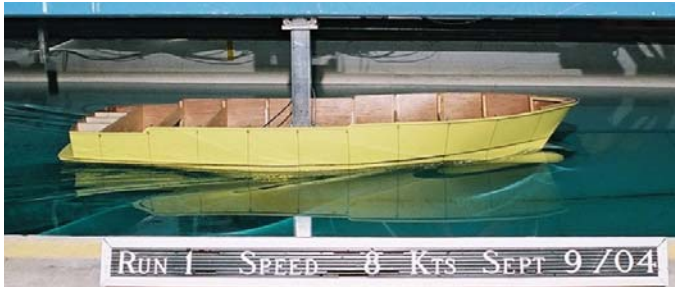


"Kookaburra" is an all-steel 76 ft ocean trawler with a 22 ft. beam and a 6.5 ft. draft. It is fitted with twin 330 hp diesels and has a top speed of 12 knots. At 225,000 lbs. (half loaded) it is considered moderately heavy. It has a 3500 mile range at 9 knots on 3300 US gallons of fuel. On a trip from Vancouver, B.C. to Mexico they easily averaged 9 knots in reasonable weather. Although their initial intention was not to cruise that fast, they started out at that pace, found it comfortable and just never throttled back. They burned about 1 US gallon of fuel per nautical mile including running the generator 3 hours per day.



Our latest project, to be launched in the spring of 2006, was extensively tank tested and much of the data in this paper is taken from that test report. It is an 86 ft. long-range sportfish with a 24.5 ft. beam and 6.5 ft. draft. It is built with a steel hull and fibreglass superstructure and displaces 245,000 lbs. half loaded. Twin 550 hp. diesels will push it up to 14 knots with a range of 7000 miles on 5500 US gallons of fuel.





The Buccaneer 108 utilizes these hull features to gain significant performance advantage. Construction is scheduled to start later this year (2006).

Future work:

For the future we will continue to look at improvements in hull design but with a focus on enhancement utilizing appendages.

Our bow bulb has been retrofitted to over 3 dozen vessels from 40 ft. to 95 ft. and model tested on designs up to 160 ft. The design parameters and real-time results have been well established by feedback from numerous clients.

The midship blisters, which show initial success, need further study to bring out their full potential and determine the exact proportions necessary to create the maximum benefits. The goal is to achieve a significant reduction in the midship wave hollow in combination with the wave reduction of a bulbous bow, which will bring a reduction in the stern wave through an overall shallower wave train. This will also contribute to increased stability underway as there is less midship trough for the vessel to heel into.

With the reduction in bow and midship waves it is only natural that we should look aft to the transom. The large reduction in bow wave needs to be matched by a similar reduction in the stern wave. How this will be accomplished is yet to be determined but there are some areas of work that hold promise, including stern bulbs.

The ultimate goal is to have a vessel that will slip through the water without any disturbance to mark its passing, the ultimate interface vehicle. We will continue this work on many of our new projects, particularly focusing on 100 ft. plus long-range motoryachts.

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Calisal S.M., McGreer D., "Application of a Bulbous Bow to a Fishing Vessel", International Fisheries Energy Optimization Working Group, 1989.

Calisal S.M. et al, Marine Technology 1993, Vol. 30, "A Resistance Study on a Systematic Series of Low L/B Vessels"