Super Fuel-Efficient Long Range Motoryachts

By Patrick J. Bray, Naval Architect

BRAY
YACHT DESIGN
AND RESEARCH

SEA FUTURE

This work is a further development from our SNAME 2006 paper, also titled "Super Fuel-Efficient Long Range Motoryachts"

- This report expands considerably from that application of our research work.
- The developed concepts have been applied to larger vessels in both re-fit and new construction.

SEA FUTURE

Over 17 years ago we started an in-house research project to increase the efficiency of long range motoryachts.

Project goals:

- A hull form efficient over a wide range of displacement and semi-displacement speeds
- Capable of long ocean passages
- Comfortable motion
- Good fuel economy

SEA FUTURE

After completing an ocean passage, the vessel can power around local waters at higher semi-displacement speeds, keeping up with faster short-range yachts while still maintaining the same high degree of comfort and fuel-efficiency, and then return across the ocean in displacement mode.

- Trans-Atlantic range or better
- Good seakeeping
- Excellent stability characteristics.

SEA FUTURE

These goals would be achieved by utilizing and enhancing the current available technology.

As an analogy for this development, compare the progression of the internal combustion engine; from the first inefficient version to it's modern day efficiency.

- 1890's –
  1.1L Daimler/Maybach, capable of 4 hp @ 900 rpm

2000's –

modern production engines of the same size now produce over 68 hp @ 6000 rpm by using the following "bolt-on" parts:

- Efficient carburetors
- Turbo chargers
- Header exhaust
- Fuel injection
- Intake and exhaust porting

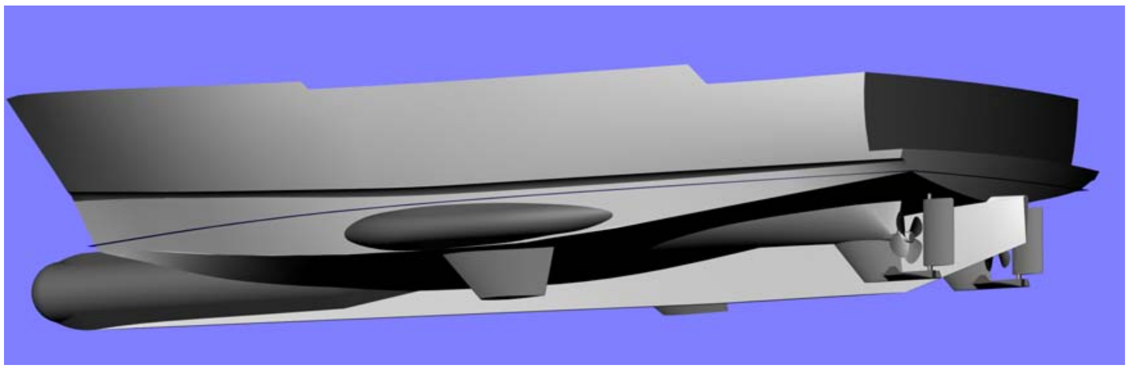
Fine tuning the design in this way has brought huge gains. These engines are lighter and more fuel efficient than the original model.

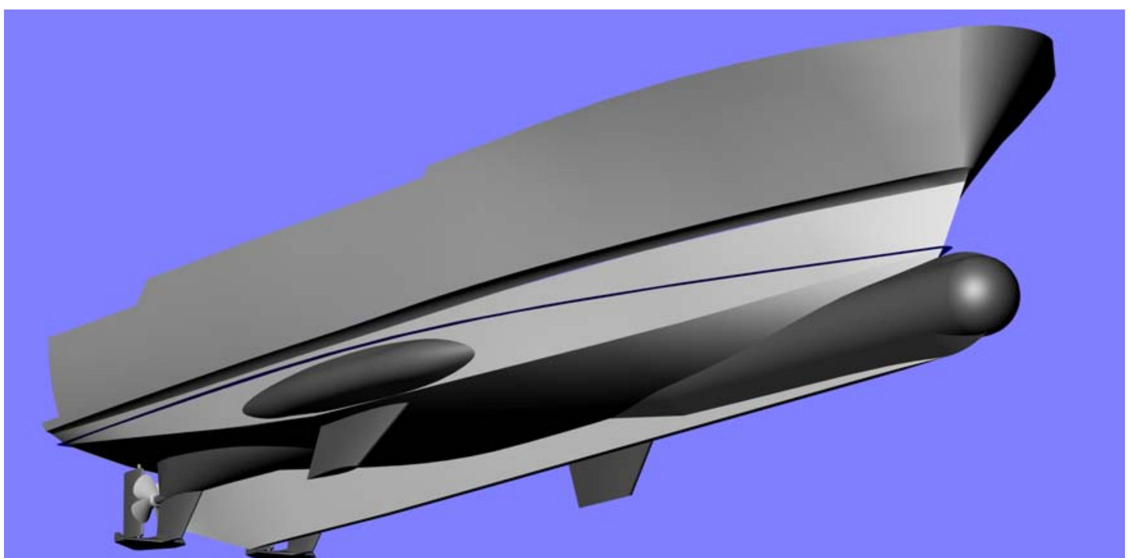
In the same spirit we evaluated the principles of a good basic hull design and then looked at increasing efficiency by utilizing enhanced "bolt-on" appendages.

By "bolting on" a bulbous bow, fixed or fixed/active stabilizers, and even stern appendages we have seen significant performance improvements.

SEA FUTURE

The rising costs of fuel and the priority of a reduced carbon footprint are creating an imperative demand for this type of technologically advanced design.





Design Priorities:

- Reduced fuel consumption
- Improved seakeeping
- Technologically advanced hull
- Increased range of stability
- Reduced wave train

In the quest for the right offshore boat, many seaworthy commercial vessels have been converted to pleasure craft, some with more success than others.

Moving forward from conversions, new, innovative designs based on trawler hulls have been developed, specifically for pleasure cruising.

These solidly engineered yet innovative craft combine practicality and comfort.

Our research work started with a paper study on various published hull forms, their relative efficiencies and seaworthiness.

Evaluation Criteria:

- Displacement, semi-displacment, and planing forms
- Resistance curves
- Seakeeping
- A Speed/length ratio of $\sqrt{LWL}$ * 0.9 – 2.3. (10 – 20 knts)

Conclusion:

- A lobster hull form was confirmed to be the most effective.

SEA FUTURE

To enhance the lobster hull and further improve performance, we mixed and matched a variety of features, such as:

- Fine bow
- Wide spray knockers/chines
- Low transom immersion

SEA FUTURE

Incorporating these design features into the styling, the boats' hidden abilities are often disbelieved, even with reality floating right at the dock.

- Efficiency is concealed in attractive lines without having to resort to unsuitable or impractical shapes.
- High-performance abilities hide in plain sight.

SEA FUTURE

Combining our hull research and available technology allows us to create significant performance gains.

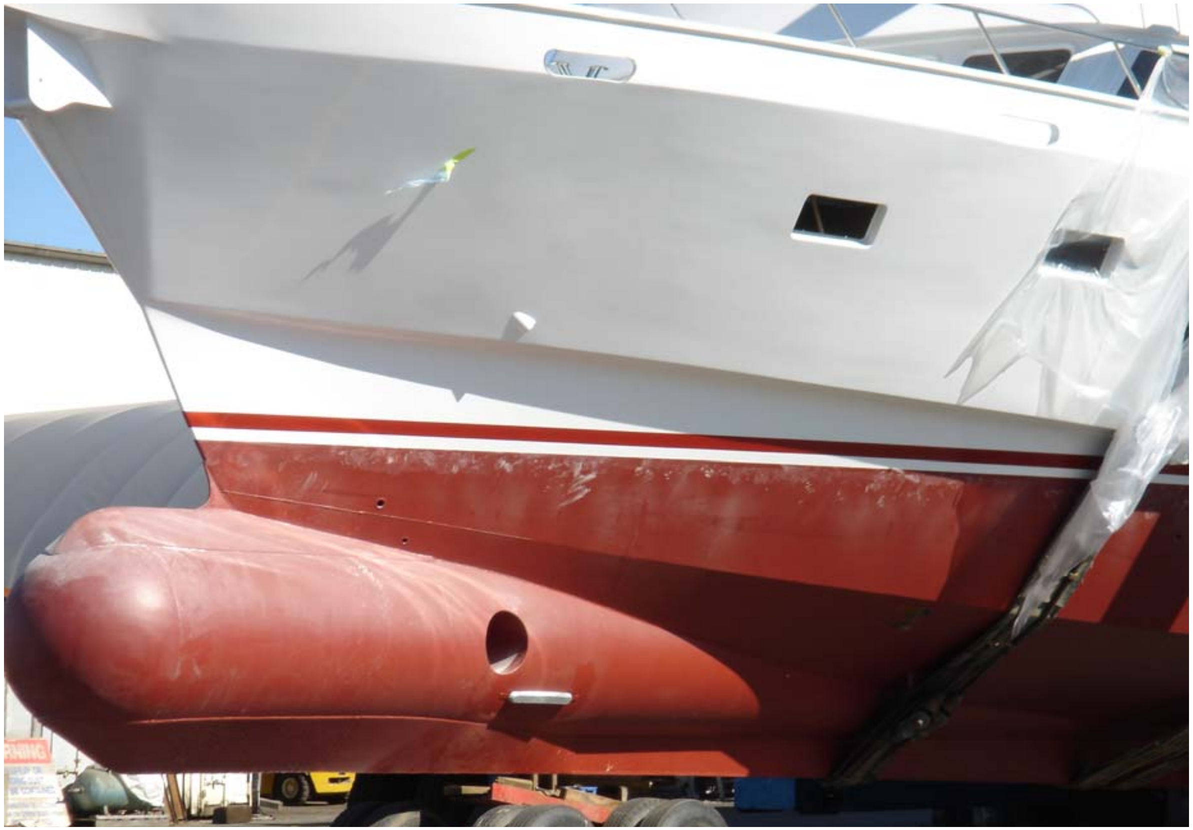
- At 6 knots our hull has no noticeable wave train.
- At 15 knots (pictured) there is considerably less wave train than most semi-displacement vessels.
- At 20 knots our semi-displacement form is equal in resistance and wave profile to a fully planing form.

SEA FUTURE

Once the hull shape was established, we started looking at adding significant appendages

- Bulbous Bows
- Bifoil Skegs
- Midship Bulbs
- Stern Bulbs

Bulbous Bows

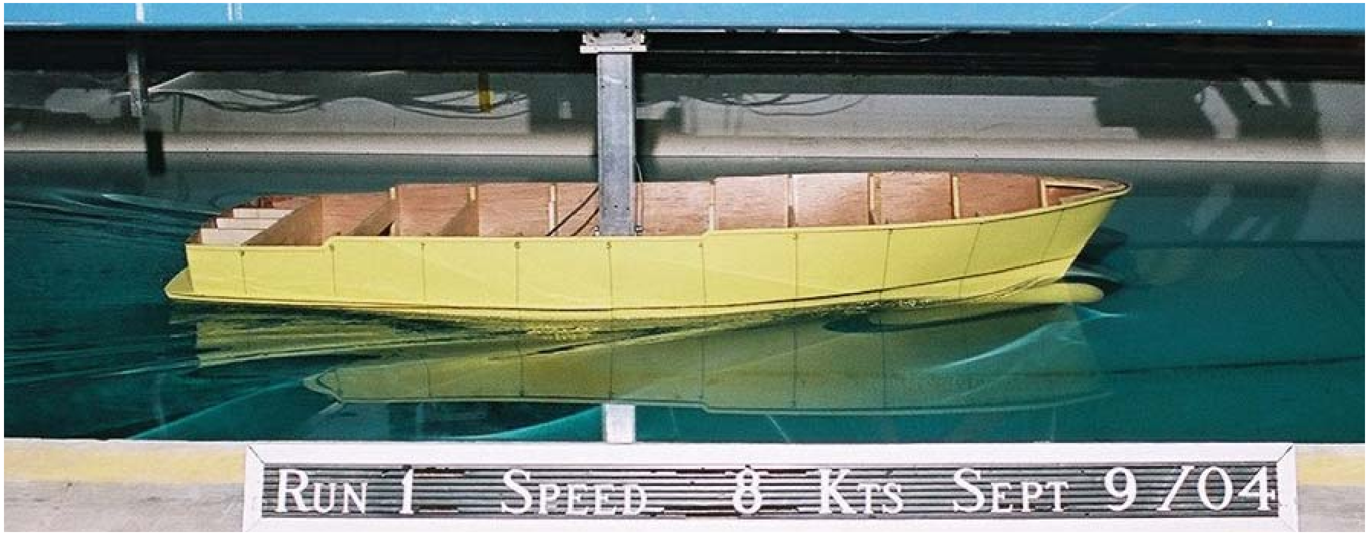


- Effective from 8 to 20 knots
- Reduces resistance up to 15%
- Reduces running trim by1 degree
- Reduces pitching by approximately 50%
- Retrofitted to over 3 dozen vessels from 40 ft. to 95 ft.

  and model tested

  on designs up to 160 ft.

The bulb accomplishes a reduction in the power required to move the boat. It does this through wave cancellation and by reduction of the running trim due to the hydrodynamic forces acting on the bulb.



Hull

With Bulb

Hull

Without Bulb

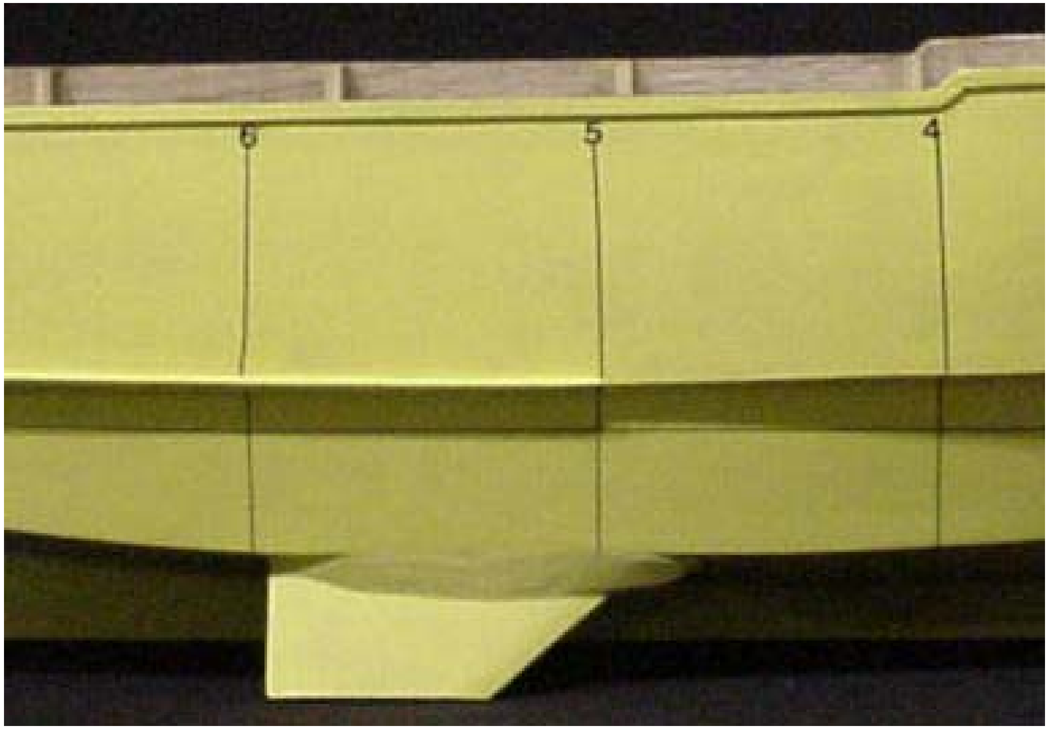
SEA FUTURE

Bi-foil Skeg

- The bi-foil skeg acts like a passive trim tab to lift the stern at hull speed and beyond giving a 7% reduction in resistance.
- It reduces pitching motions at the stern by 30%.
- Optimization of the plan form and utilization of a hydrodynamic foil section makes these appendages more effective and efficient.

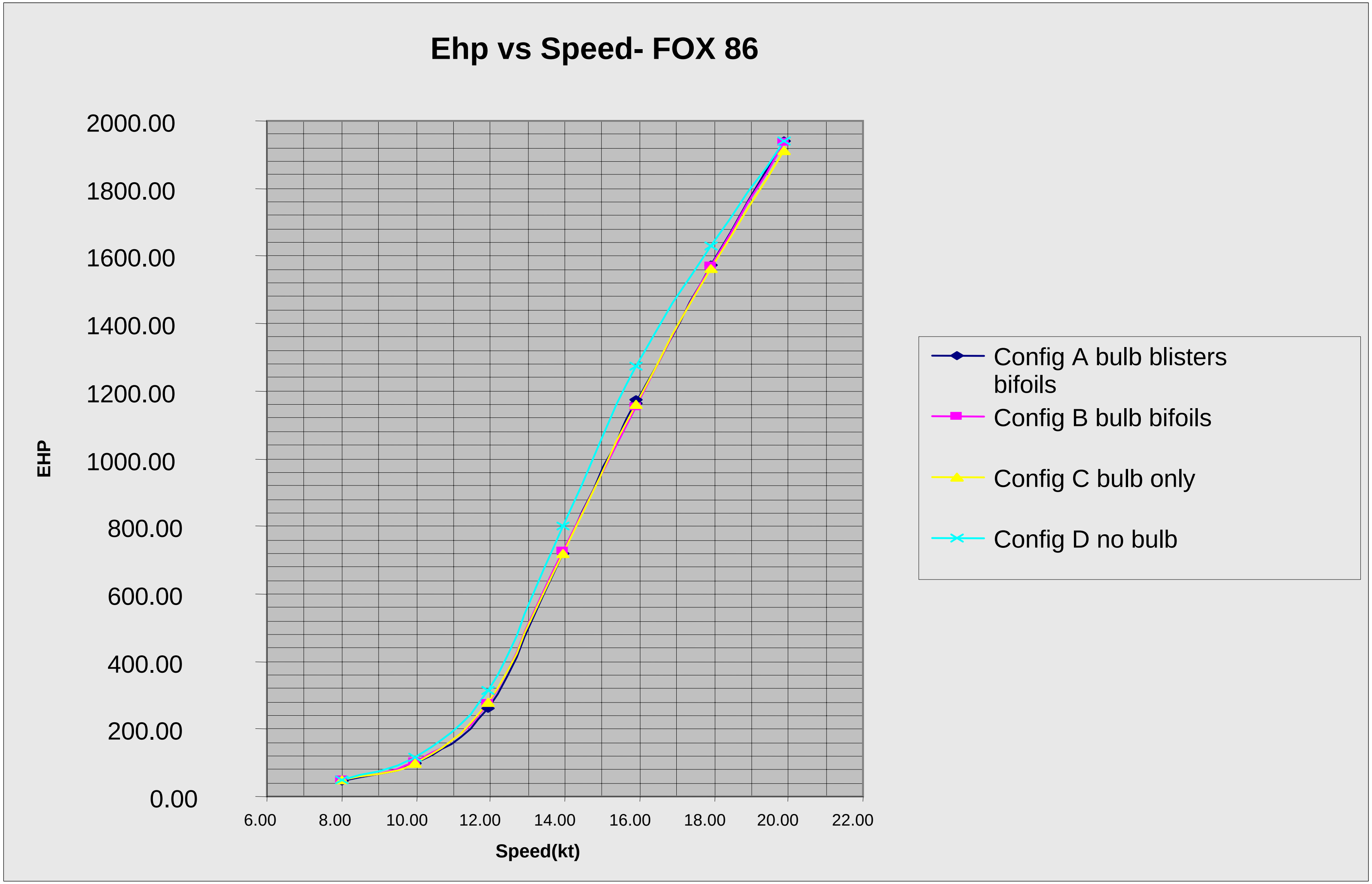
SEA FUTURE

Midship Bulbs



- These significant appendage fairings are effective from 8 to 16 knots in creating a reduction in the midship wave train hollow.
- Reports show these fairings reduce the overall resistance 6% to 10%.
- A shallower wave train results in increased stability under way as there is less midship trough for the vessel to heel into.

Powering Predictions



Comparison of Bray Hull to a Typical Trawler Hull

Typical Trawler Hull at 10 knots

Bray Trawler Hull at 10 knots

At 10 Knots:

Our Trawler has:

- Less bow wave
- Less midship hollow
- Less resistance

SEA FUTURE

Comparison of Bray Hull to a Typical Trawler Hull

Typical Trawler Hull at 13 knots

Bray Trawler Hull at 13 knots

At 13 Knots:

Our Trawler has:

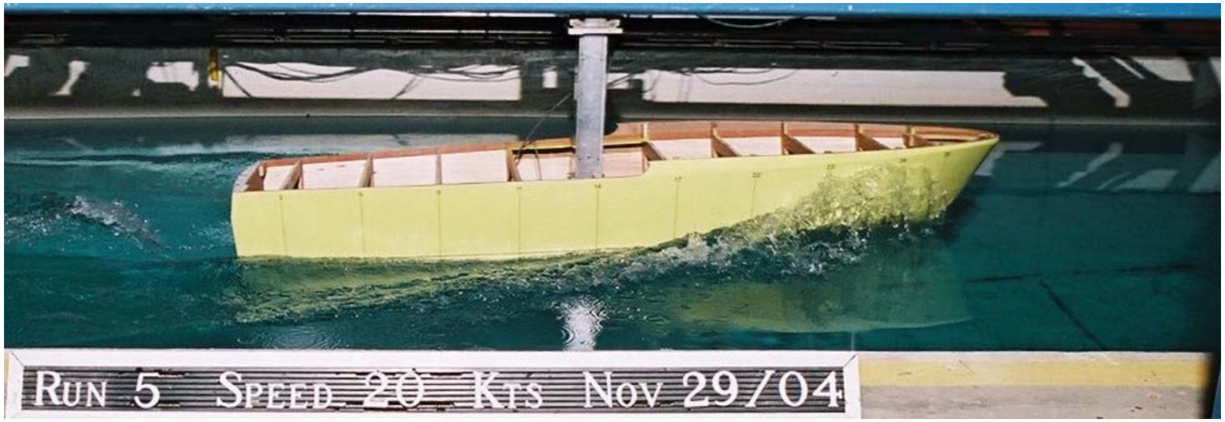
- Much less bow wave
- Much less midship hollow
- Much less resistance

SEA FUTURE

Powering Comparisons

Speed	SHP		GPH		Range		Gal/mile		%
	Typical	Ours	Typical	Ours	Typical	Ours	Typical	Ours	Difference
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

Comparison of Bray Hull to a Semi-Planing Hull



Typical Hull at 20 knots

Bray Hull at 20 knots

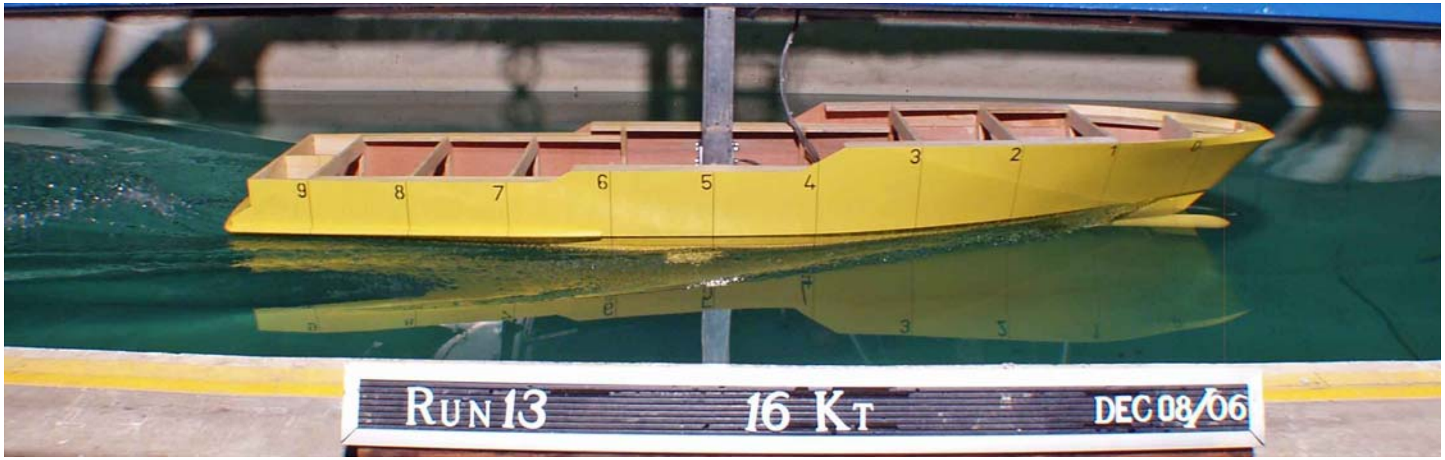
At 20 Knots:

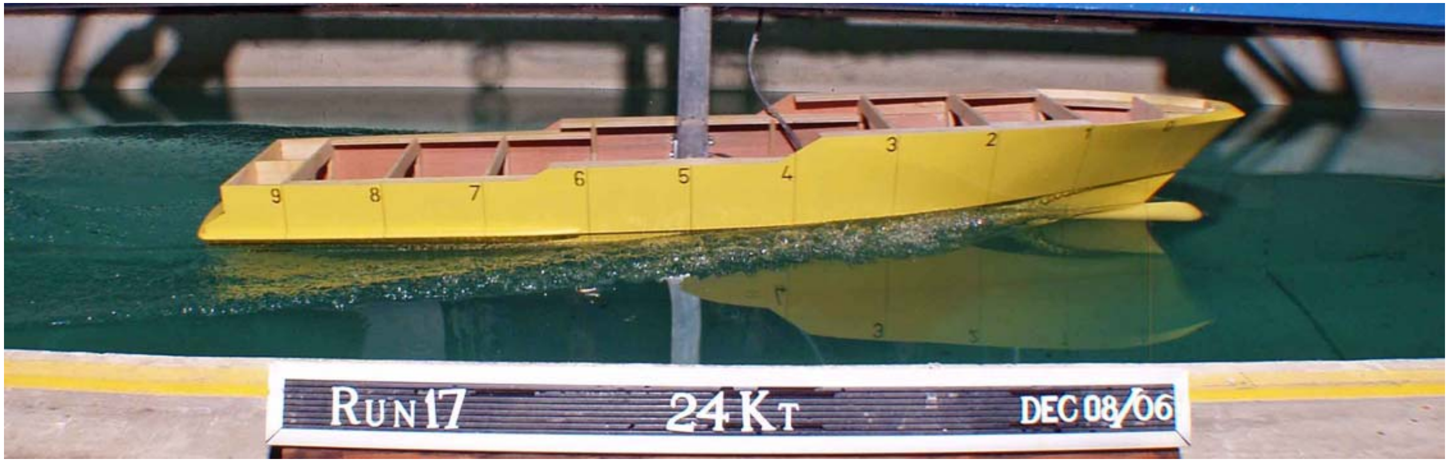
Our advanced form has:

- Much less bow wave
- Much less resistance

SEA FUTURE

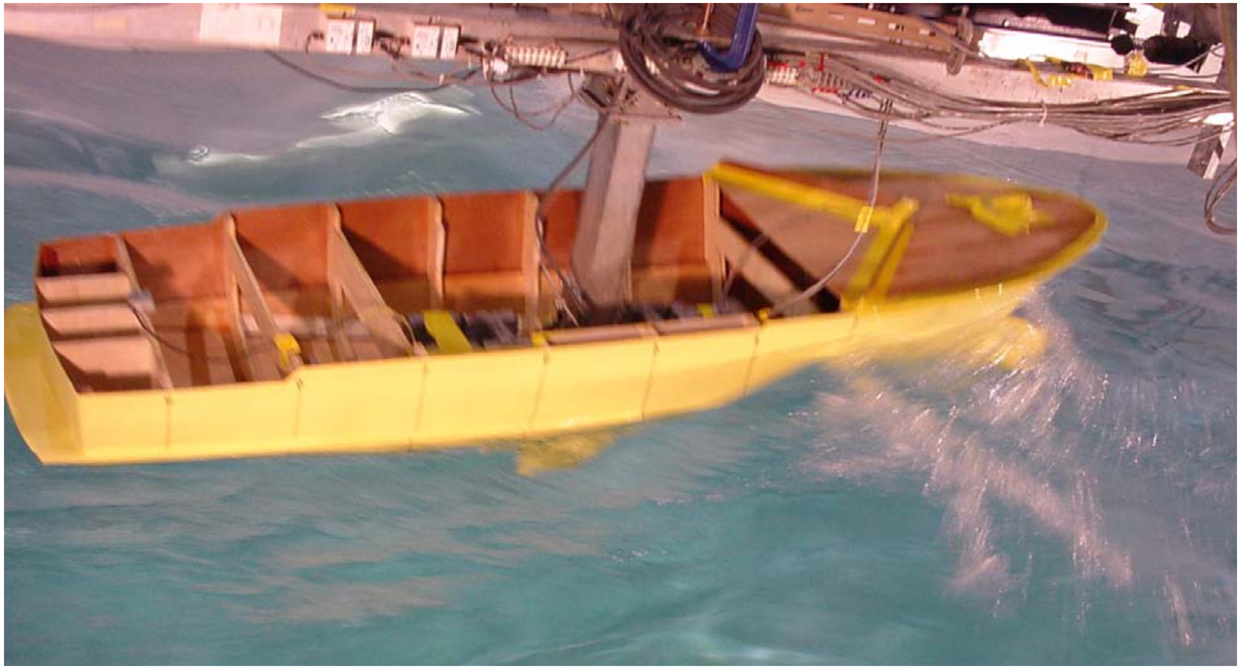
Model testing of the Bray hull shape





Even at 24 knots there is no water coming up the bow higher than the spray knocker/chine. Owners of these vessels report that they are an extremely "dry" boat.

Superior Seakeeping



The reduced bow wave height means that when the bow enters a large wave there is less water being pushed aside so there is less water to come on deck.

Added appendages and slick hull form give superior sea keeping characteristics. The vessel can operate economically at a higher speed (2 knots faster) with no reduction in the degree of comfort.

Seakeeping Data

Seastate	Speed (kt)	Bow Accelerations (g - rms)	CG Accelerations (g- rms)	Stern Accelerations (g-rms)
Config B with bulb and bi-foil				
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**
Config D no bulb, no bi-foil				
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

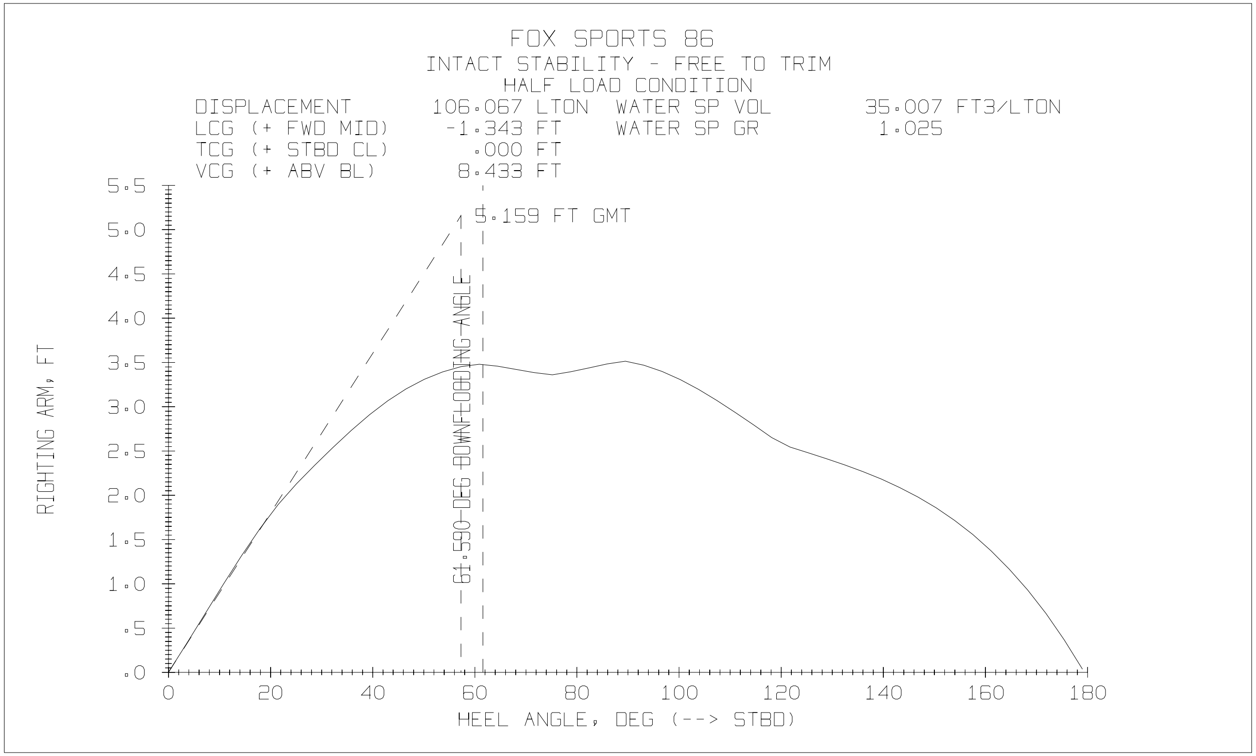
Seakeeping Evaluation

- It can be seen from the previous 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 advantage 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 wave height of 3.5 - 4.0 ft. with a wave period of 5.8 seconds.
- Sea-State 5 is defined as having a wave height of 8.0 – 12.0 ft. with a wave period of 8.25 seconds.

Stability

All of these other features would be for nothing if the hull form 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. This hull handles those issues easily, having not just stability to meet the minimum requirements of International Authorities but a good, healthy range of stability.



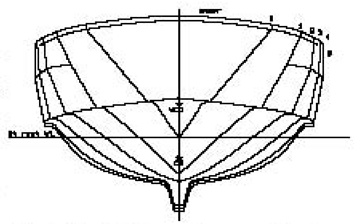
- Good Initial GM
- Good Maximum GZ angle
- Excellent overall range of GZ

STABILITY – WHAT IS IT AND HOW DOES IT WORK?

"Eastland" disaster, July 1915

Stability is the ability of a vessel to return to a previous position. Positive stability would then be to return to upright and negative stability would be to overturn. Stability in it's most basic form is the relationship between the center of all floatation in your hull (center of buoyancy, or CB) and the center of all weight (vertical center of gravity, or VCG). In other words, the downward pull of Gravity and the uplifting force of Buoyancy. These are the primary characters in this scene and all others play minor roles. Once you understand how their relationship works, understanding stability becomes a simple matter.

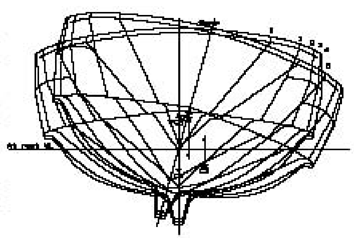
Static stability



This is stability at rest without active external forces at work. The VCG for all intended purposes is a fixed point in space and is a reflection of the placement of major weights within the boat affected in part by the amount of superstructure and number of decks.

The shape of the hull determines the CB, which is not fixed. It moves around to balance the loads and keep the forces in equilibrium. The shape of the hull has a major effect on the path that the CB will take as the vessel heels or trims. At rest the CB and the VCG align vertically. If they are not vertically aligned then the vessel will change trim or list until they do come into alignment. Then all the forces are equalized and the vessel becomes stable.

Form stability (effects of section shape)



As the boat heels, sides of the boat previously above water are immersed and bottom sections previously underwater are now exposed, and the CB is on the move. The battle has begun. As forces are applied to the vessel changing it's attitude in relation to the surface of the water. This causes the CB to move, creating the forces to bring the vessel into equilibrium. If the CB can not create enough counterforce to right the vessel then it will be over turned.

- 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.

SEA FUTURE

Sample Vessel "Amnesia IV"

LOA: 26.2m (86 ft.)

Beam: 7.0m (23 ft.)

Draft: 1.8m (6 ft.)

Displ: 95.3t (210,000 Lbs)

Power: 1 x 1300 hp MAN Diesel

Top Speed: 15 knots

Range: 7000 Nautical miles at 9 knots

SEA FUTURE

Sample Vessel "Amnesia IV"

- "Amnesia IV" was one of our first large fiberglass motoryachts to take advantage of this developing technology.
- She is 86 ft. long with a 23 ft. beam and 6 ft. of draft.
- With a single 1300 hp MAN diesel she achieved a top speed of 15 knots.
- At 210,000 lbs. displacement (half load) she is considered to be a medium weight vessel.
- This yacht 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.

SEA FUTURE

Sample Vessel "Kookaburra"

LOA: 23m (76 ft.)
Draft: 2m (6.5 ft.)
Power: 2 x 330 hp John Deere Diesels
Range: 3500 Nautical miles at 9 knots

Beam: 6.7m (22 ft)
Displ: 102t (225,000 Lbs)
Top Speed: 12 knots

Sample Vessel "Kookaburra"

- **"**Kookaburra**"** is an all-steel 76 ft ocean trawler with a 22 ft. beam and a 6.5 ft. draft.
- She is fitted with twin 330 hp diesels and has a top speed of 12 knots.
- At 225,000 lbs. (half loaded) she is considered moderately heavy.
- She has a 3500 mile range at 9 knots on 3300 US gallons of fuel.
- On a trip from Vancouver, B.C. to Mexico the yacht easily averaged 9 knots in reasonable weather. Although the 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.

Sample Vessel: "No Boundaries"

LOA: 26.2m (86 ft.)

Draft: 2m (6.5 ft.)

Power: 2 x 550 hp Caterpillar Diesels

Range: 7000 Nautical miles at 9 knots

Beam: 7.46m (24.5 ft.)

Displ: 111t (245,000 Lbs)

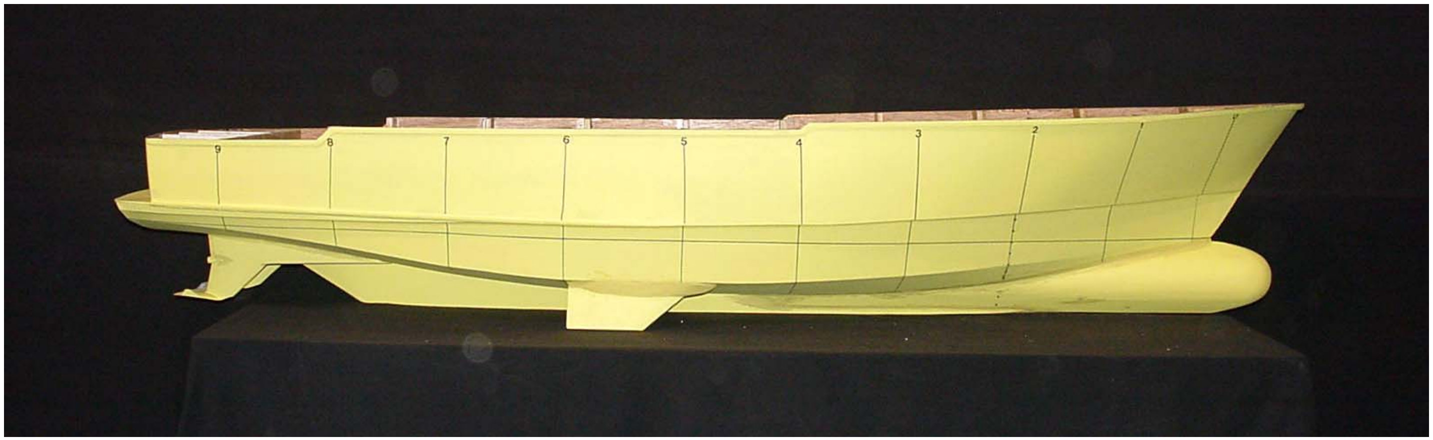
Top Speed: 15 knots

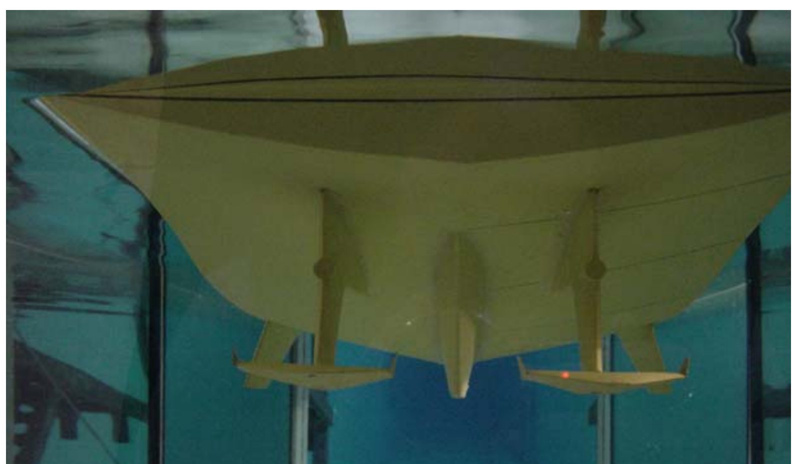
SEA FUTURE

Sample Vessel "No Boundaries"

- This vessel was launched in the spring of 2006 and was extensively tank tested. Much of the data in this paper is taken from that test report.
- She is an 86 ft. long range sportfish with a 24.5 ft. beam and 6.5 ft. draft.
- She is built with a steel hull and fibreglass superstructure and displaces 245,000 lbs. half loaded.
- Twin 550 hp. diesels will push her up to 15 knots with a range of 7000 miles on 5500 US gallons of fuel.

Moving forward, we continue to look at improvements in hull design with a focus on utilizing enhanced hull appendages.

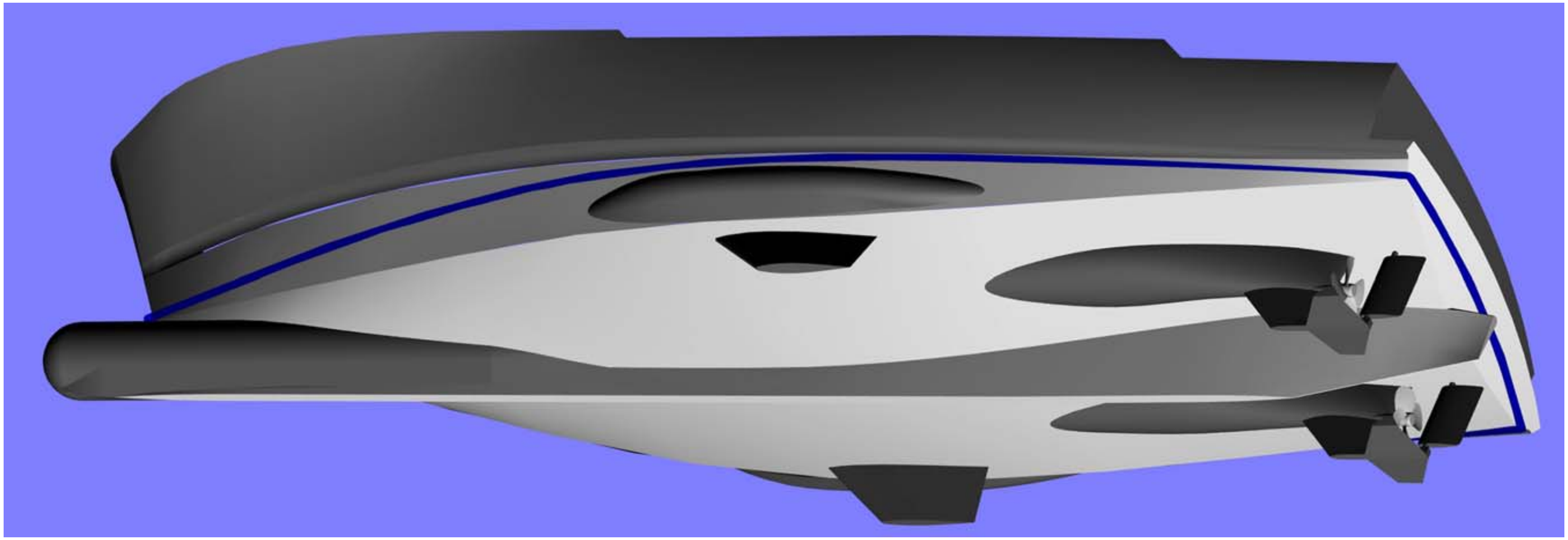




Stern wave reduction is currently undergoing research

- 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.
- The exact parameters are undergoing study and there are several areas of work that hold promise, including stern bulbs.
- To date stern bulbs have shown as much as 7% reduction in resistance.

Reductions in Resistance



Bow bulb -15%

Midship bulb -10%

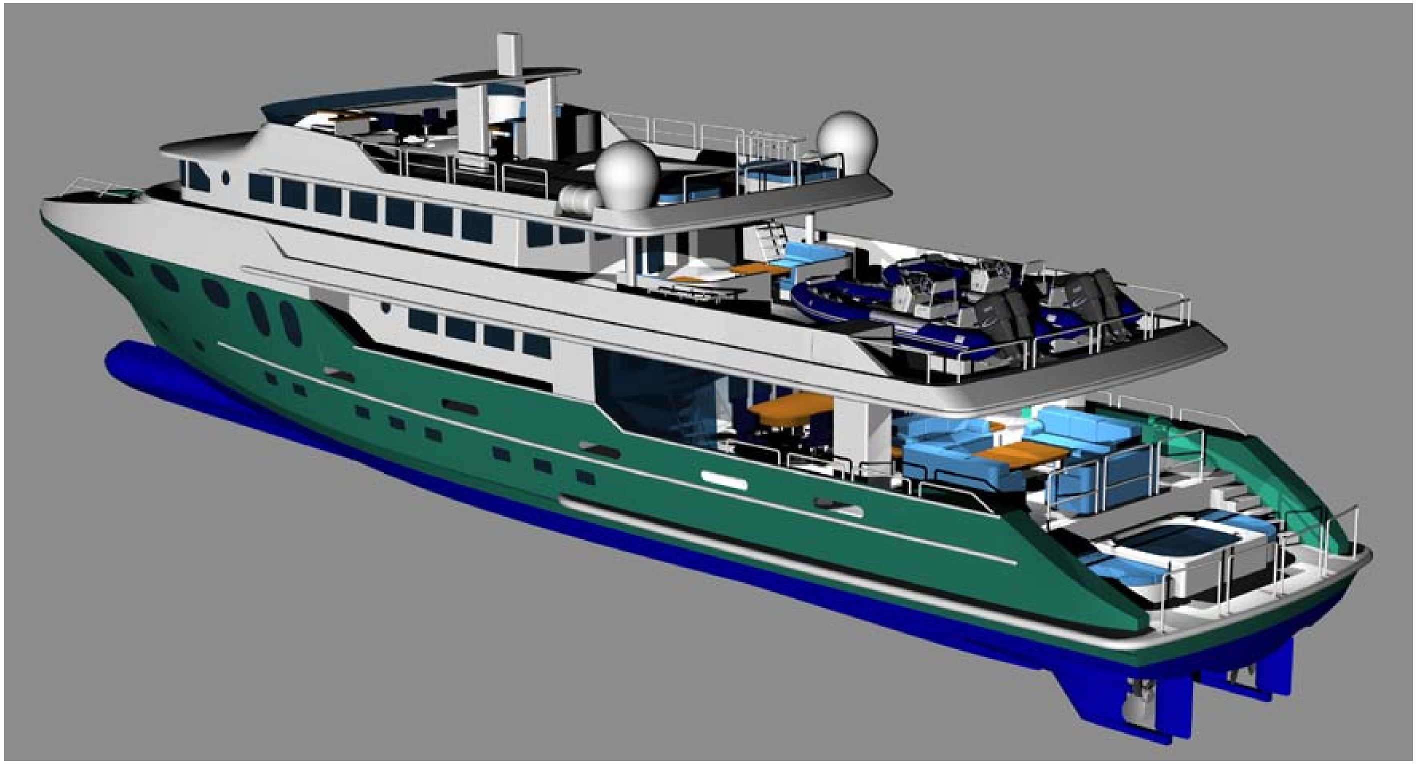
Bi-foil skeg - 7%

Stern bulb - 7%

There are total reductions of up to 50% when utilizing a refined hull form such as the Bray hull, combined with these appendages.

The volume of the appendages accounts for 15% of the vessel displacement. This allows the hull form to be finer, narrower, and shallower, reducing hull resistance even further.

New research looks toward vessels over 100 ft. (30m)



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.

SEA FUTURE

New projects utilize this hull technology to give superior fuel-efficiency and performance in a wide variety of styles and lengths.

Expedition Yachts

Long-Range Cruising Yachts

SEA FUTURE

Motor Yachts

Explorer Yachts

BRAY
YACHT DESIGN
AND RESEARCH

PO BOX 75175, WHITE ROCK, BC, V4B 5L4, CANADA

604-531-8569

www.brayyachtdesign.bc.ca

By Patrick J. Bray, Naval Architect