A Discussion on Hull Form

An Abaco is not just another high quality, pretty "blue boat." To fully understand why an Abaco excels as a cruiser, you have to look deep-deep into the hull, drive, propulsion, and steering systems.

Power boats, even cruising power boats, are being designed to travel at higher and higher speeds. A few years ago, thirty knots was considered a high top end speed for cruising boats. Today, some cruising planing boats are being designed to achieve forty knots. What is causing this push for higher speeds? And what performance and seakeeping sacrifices are made to achieve these higher speeds?

PROPULSION

The performance characteristics of a power boat are based on four simple parameters: the drive and propulsion system, the hull shape, the weight or displacement of the boat, and the distribution of the heavy components such as engine, propulsion system and tanks.

Originally, power boat propulsion systems were simply straight fixed shafts delivering power from the engine to a propeller. In the last few decades, however, three alternative propulsion systems have evolved.

Water jets have replaced propellers in some applications, such as military landing craft needing very high speed combined with shallow draft and propulsion protection. Jets are also used on some high end pleasure, but not working, boats operating in fish-trap infested waters.

More recently, outboard drives and pods have become popular on small to mid-sized pleasure boats because, at very high speeds, they are more efficient than twin engines driving straight shafts and propellers. The propellers on the outboard drives and pods, like jets, are positioned parallel to the direction the boat is travelling, as opposed to a slight incline necessary with most straight shaft arrangements. In addition, outboard drives and pods can accommodate twin counter rotating propellers. Further, jets, outboard drives and pods eliminate the need for rudders, thus reducing surface area and, hence, frictional drag. Finally, forward facing props are considered, by some, to be more efficient than aft facing props.

The performance shortcomings of jets, outboard drives and pods relative to straight shafts is that they weigh more than straight shaft propulsion systems. As a result, they are only more efficient than straight shafts at higher speeds above, roughly, 25-30 knots, where their greater efficiency overcomes their added weight.

Modern power boats, with fiberglass hulls and diesel engines, have long lives. As a result, new recreational

boat sales are highly dependent upon having a new product offering. Very high speed, achieved with jets and pods driven by powerful engines is an enticing sales proposition. Today, many mid-sized boats are sold with these drive systems. But at what cost? And why?

There is a telling quote among experienced boat sales people, not often shared with their clients:
"**Customers buy speed - but don't use it.**"

HULL SHAPE

In order to achieve high speeds a boat must plane, travel along the surface of the water. Planing is most easily achieved, with minimal power, if the bottom of the hull is flat. This is the shape used on shallow water skiffs travelling in predominantly flat water.

However, a planing flat hull traversing moderate to heavy waves is very uncomfortable. When the boat drops off a wave, it slams. The resulting shock on landing is too severe for most passengers.

The shock when falling off a wave can be reduced substantially by using a V shaped hull, as opposed to a flat hull. And the deeper the V, the lower the shock.

But, a V shaped hull does not plane easily. To achieve easier planing, most deep-v hulls have lift strakes incorporated into the hull. The strakes have two purposes: they lift the hull out of the water at lower speeds, and they reduce the speed and, thus the shock, at which the hull re-enters the water while falling off a wave.

However, even with strakes, deep-v hull shapes have difficulty transitioning from displacement speed (roughly 6-7 knots) to a "sustainable planing" speed (roughly 20-24 knots for a conventional 40 foot deep-v hull). Achieving "sustainable planing" mode becomes more difficult and, in some cases, requires more speed as the waves become larger; the waves alter the boat speed.

Although a deep-v hull shape is more comfortable than a flat hull in moderate to heavy seas, deep-v hulls are uncomfortable at speeds between displacement and sustainable planing, in the 6-7 through 20-24 knot range. At this transitional speed range, the hulls struggle to climb their bow wave. As a result, the bow of the hull rises, impairing both visibility and steering.

Increasing the top end boat speed from, for example, 30 knots to 40 knots, requires an increase in the depth of the V to reduce the increased shock resulting from the higher speed. To make matters worse, at the higher speed more of the boat leaves the water when exiting a wave. Therefore, the higher the top end design speed, the deeper the V requirement and the further aft the V must extend.

As a result, the deeper the V and the further aft the V runs, the more difficulty the hull has in climbing its bow wave to achieve a sustainable planing mode. Climbing the bow wave is impaired even further by the added weight of the higher powered engine and associated tankage and structure required to drive the boat faster.

In summary, to achieve a faster top end boat speed with a comfortable ride, the width of the transition speed range, from displacement to planning, increases and the more the boat designer must sacrifice comfortable performance during the longer transition speed range.

WEIGHT DISTRIBUTION

Another method for increasing boat speed is reducing wetted surface, whether the hull itself or the appendages that hang from the hull, such as rudders and propulsion systems.

One simple method of reducing the wetted surface of the hull is to distribute more of the weight aft, causing the bow to rise and reducing the wetted hull surface as speed increases, which, in turn, increases speed even further. This phenomenon is most apparent in racing boats and outboard driven sport fishing boats. It is now common on some cruising boats.

A problem with decreasing wetted surface by lifting the bow is that the boat has a propensity to slap the water, even in mildly choppy seas. The bow can be lowered, of course, by using trim tabs, however, heavy application of trim tabs increases drag and negates the benefit of the reduced hull surface area in the water. Perhaps one of the more extreme examples is a new deep-v design with three inboard engines and pods mounted near the stern of a relatively long and narrow hull, combined with computer controlled trim tabs to reduce excessive bow rise in moderate to heavy seas; a heavy cost in mechanical and technical complexity to achieve high speed and fuel efficiency.

Experienced sail boaters and racing car drivers understand the merits of concentrating the weight in the centre of the boat or car. Ride and comfort improve substantially. When the weight is concentrated aft in a power boat, equivalent weight, perhaps in the form of tankage, must be located forward to balance the boat. The result is a barbell effect with a tendency to pitch.

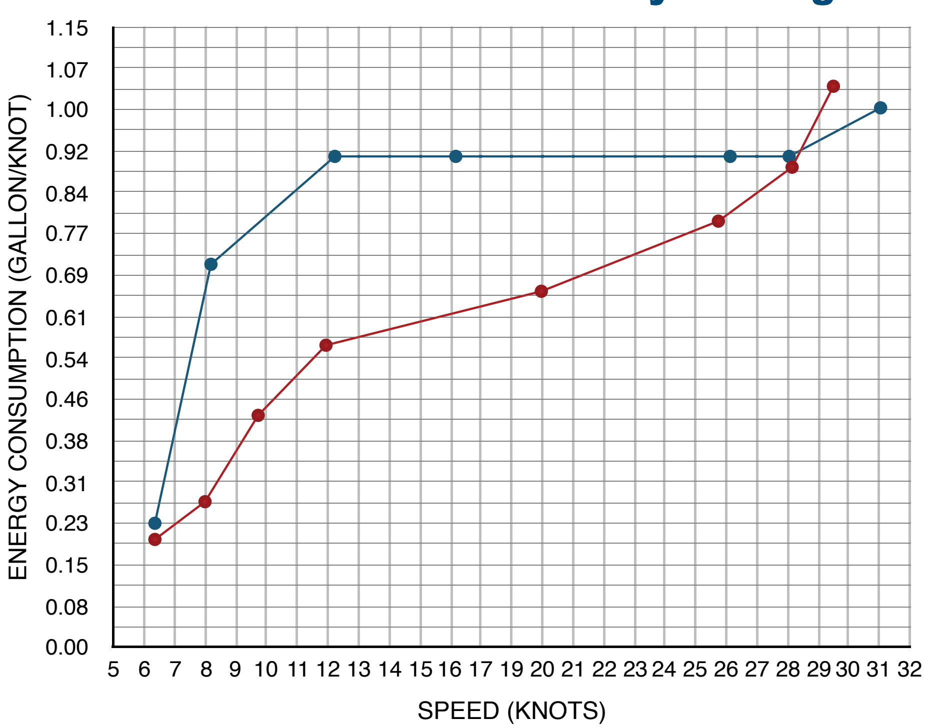
If the aft weight consists of engines as well as jets or pods, not only does the center of gravity shift aft, it shifts up. From a seaworthiness perspective, locating the center of gravity low and in the centre of the boat is much preferable. In addition to centering the weight, a single engine, which can sit lower on a V shaped hull, is preferable to twin engines, which must be positioned higher. For proof, consider the engine placement on working boats, lobster boats or trawlers.

Another reason for locating the engine and propulsion system aft is to increase volume forward for more accommodations. Again, a heavy price to pay in seaworthiness for, in most cases, less than adequate accommodation. (Your sister-in-law won't sleep under the salon sole.)

EASY PLANING HULL

An easy planing hull is one which can transition from displacement to planing mode at very low speed, in the order of 10-12 knots. In fact, the transition from displacement to planing is barely noticeable to the boat operator of an easy planing hull; bow rise is minimal, power requirements are low and steering is not impaired.

Chart 1 - Easy Planing vs Deep-v



	A40	H37
LOD	39'3"	36'11"
BEAM	12'9"	11'3"
DRAFT	3'11"	2'1"
DISP	19,000	19,000
ENGINE	CUMMINS	VOLVO
	QSM 11	D4
	670 HP	2X300HP
DRIVE	PROP/ SKEG	2 JETS

Wide open speed can be at least as high on an easy planing hull as with a conventional deep-v hull shape. Similarly, any propulsion system can be used on both hull shapes.

There are two primary differences between the performance of an easy planing hull and a deep-v hull. Both have a deep V forward to part the water easily and soften entry into chop or heavier seas. The differences relate to their performance when transitioning from displacement to planing speed, the range most operated in congested areas as well as in heavier seas.

Unlike a deep-v hull, an easy planing hull is comfortable in the speed range encountered by a deep-v hull when transitioning from displacement to planing mode. The easy planing hull has no speed range limitation. By comparison, the deep-v hull is not only very uncomfortable when operated in the transition speed range, but requires substantially more power to make the transition.

The difference between the power requirements of the two hull shapes is obvious on Chart 1 which compares two cruising boats of identical displacement. Boat A is a Bruckmann Abaco easy planing hull and boat H is a conventional deep-v with jet propulsion.

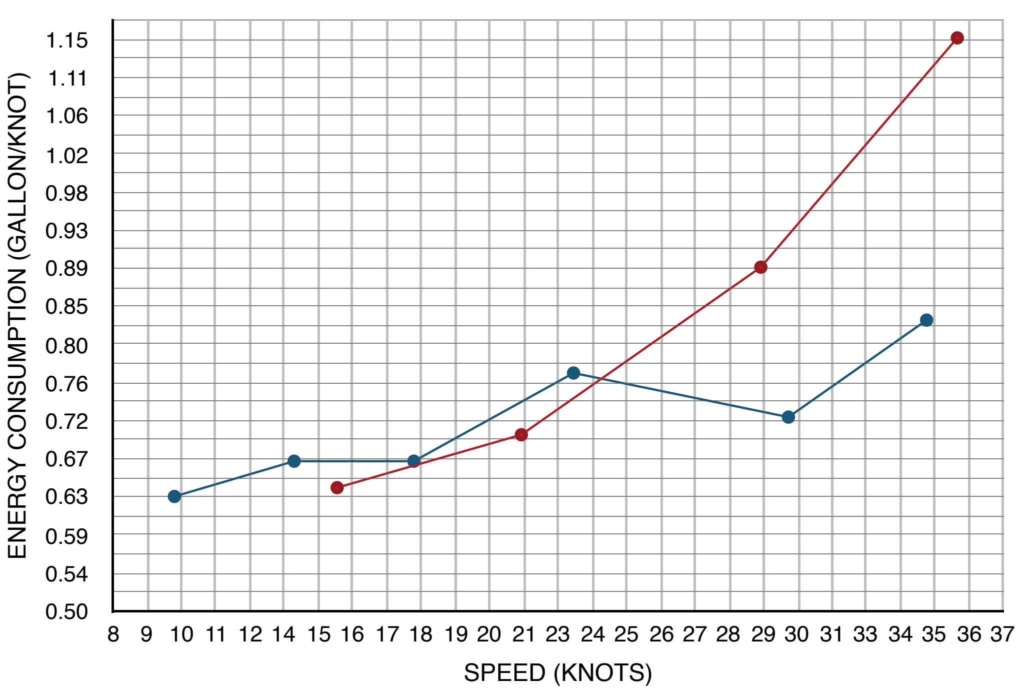
Unfortunately, the chart does not show the difference in the bow rise of the hull while in the transition mode. It does, however, show the substantial difference in power requirement, which is indicative of the difference in difficulty the two different hulls experience when climbing their bow wave.

Both hull forms, the deep-v and the easy planing, are effective at high speed in flat water, however, operators use them differently in heavy water. The deep-v can be operated at either displacement speed, or, at or above sustainable planing speed but the deep-v hull is very uncomfortable in the transition speed range, especially in heavy water. In contrast, the operator of an easy planing hull has the option of reducing shock and increasing comfort and safety (running too fast down a wave in a following sea) by staying on a plane at reduced speed, below that required to sustain planing with the deep-v.

Where the easy planing hull comes up short, relative to a deep-v hull, is when planing fast in heavy seas. The easy planing hull flattens towards the aft; this is part of the hull design feature that keeps the hull relatively level when in transition mode. In heavy seas, the flat aft section is not as forgiving as a deep-v aft shape when falling off a wave. The easy planing hull is best throttled back in heavy weather, a mode the operator of a deep-v hull is likely to also prefer but is limited in practicing.

The deep-v hull shape is preferable if the boat must travel fast regardless of sea conditions, the situation faced by pilot boats or deep sea sport fishing boats. On the other hand, the easy planing hull is especially attractive for cruising, being most comfortable and seaworthy when combined with the appropriate propulsion and tracking systems, and when weight is properly positioned.

Chart 2 - Same IPS 2 x 370 HP on Abaco 40 vs Deep-v 40



	A40	DEEP-V 40
LOD	39'3"	40'0"
BEAM	12'9"	12"0"
DRAFT	~3'3"	~3'3"
DISP (DRY)	19,000	18,910

DISPLACEMENT

As shown in Chart 1, an easy planing hull is much more easily driven than a deep-v hull. Therefore, the easy planing hull requires less power, which reduces fuel consumption, which reduces fuel storage requirement. Lower power and fuel storage requirements reduces structural requirements, all of which reduces displacement - which, in turn, reduces even further power, fuel and structural requirements. A virtuous circle.

The Abaco shown in Chart 1 has the same displacement as the deep-v boat, but has 13% more beam and 6% more length. In total, the Abaco hull has approximately 20% more volume and is a much more stable platform.

DRIVE SYSTEM

As noted earlier, an easy planing hull can be driven with the same engine and propulsion systems as a deep-v hull, however, the easy planing hull requires less power. Chart 2 compares the performance of an Abaco easy planing hull to that of a popular deep-v hull of almost the exact same displacement and volume. Both are driven by exactly the same pod drive systems; however, the engines are centred on the Abaco but positioned aft on the deep-v. As would be expected, the easy planing hull, because it is more easily driven, achieves noticeably higher top end speed. As an aside, it is worth noting that at speeds above the low 20's, the deep-v hull is somewhat more fuel efficient. We speculate that this is because the deep-v bow rises at higher speeds (due to the far aft location of the engines), reducing wetted area, and thus friction, increasing fuel efficiency - but, as noted earlier, at a cost. The deep-v hull with the raised bow is less comfortable in choppy seas.

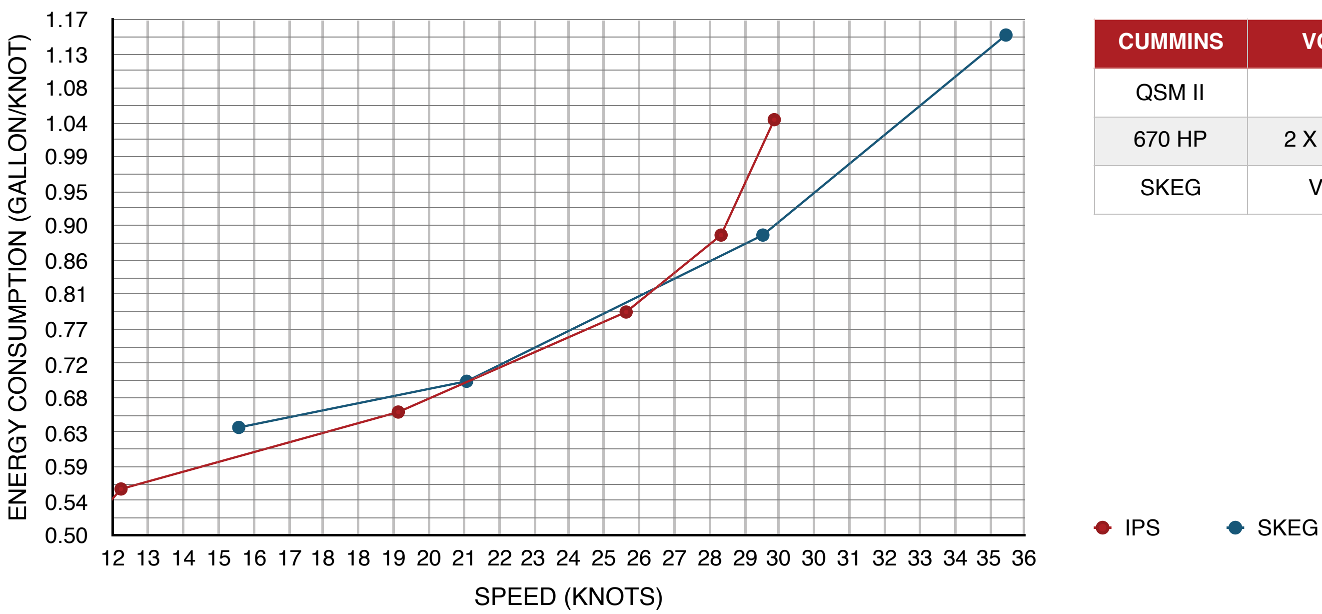
The dilemma faced when deciding on a drive system for the Abaco was whether to use the currently popular system of twin engines driving twin pods, as shown in Chart 2, or to use a drive system composed of a single engine driving a fixed shaft and propeller, protected with a skeg. Although not well understood, both are approximately equally efficient up to the top cruising speed for the single engine system. A comparison of the performance of the two different drive systems on the same easy planing hull is shown in Chart 3.

The easy planing hull with a twin pod drives delivers higher top end speed than a fixed shaft system. However, a fixed shaft system can be protected with a skeg and steered with a rudder, a much simpler, safer, lower maintenance, and dependable system. Hence the dilemma; popular higher top end speed or a protected propulsion system? At comfortable cruising speeds, the fuel efficiency is the same.

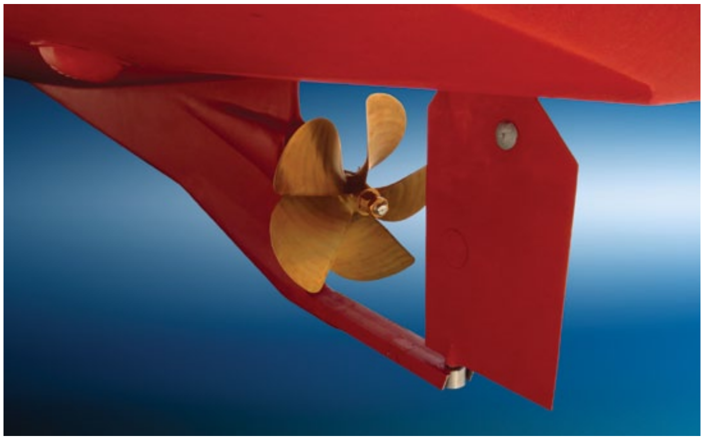
SINGLE ENGINE, SKEG, FIXED SHAFT, RUDDER

Although Abaco tooling is designed for both twin or single engines, to date, all Abaco 40's have been built with a single engine, fixed shaft, skeg and rudder. As noted above, this system is simpler, safer, requires less maintenance and is more dependable than a pod system. Although a pod system will deliver extremely high top end speeds on an easy planing hull, a pod system can easily foul or be damaged, is difficult to maintain and is dependent upon

Chart 3 - The Dilemma: Abaco 40 Hull with Single/Skeg or IPS?



CUMMINS	VOLVO
QSM II	D6
670 HP	2 X 370 HP
SKEG	V-AFT



computers for steering. In salt water, computers tend to fail at inconvenient times.

Many pod propulsion systems are promoted due to their supposedly superior manoeuvrability. However, today, manoeuvrability of a single engine boat is a non-issue. Oversized variable speed bow and stern thrusters on a single engine boat make them substantially more manoeuvrable and intuitive than twin engine driven pod or jet drives, even with bow thrusters.

In addition to the skeg adding directional stability, especially important in a following or quartering sea, the skeg protects the propeller from fish traps, nets, ropes, debris and grounding. It also eliminates the thick column of water which otherwise forms around a rotating shaft and induces drag (the "Magnus Effect"). And a fixed shaft provides a location for line cutters in the unlikely event a rope somehow by-passes the skeg.

Further, the skeg system is more seaworthy in the event of engine failure. If the engine fails, the captain can always drag a sea anchor and steer with the large rudder attached to the skeg. Most diesel engine failure results from bad fuel, a condition that will impact both engines on a twin engine boat. (Those comforted by redundancy will take comfort in knowing marine diesels are mandated to have "get home" capability.) Little wonder a protected propulsion, single engine drive system is favoured by most commercial fishermen, even king crab fishermen at sea for a month at a time off Alaska during mid winter.

In addition to the logic above, the answer to the drive system dilemma was reinforced by the reply from a young captain (young folks like new stuff) on a luxury cruise ship. The captain was asked why his company's most recently launched ship, the industry's most luxurious, was built with twin fixed shafts, as opposed to the theoretically more efficient twin forward facing pod systems used for many years on sister ships. The captain said, "Simply put, pods are just plain dangerous."

EVOLUTION OF THE EASY PLANING HULL SHAPE

Designer Mark Ellis and builder Mark Bruckmann first combined to create an easy planing hull shape in 1994. Since then Ellis has designed easy planing hulls for boats of various sizes, some built by builders other than Bruckmann. Bruckmann has built easy planing boats of 34', 40', 44', and 56' length. The Abaco 40 is Ellis' seventh easy planing hull design iteration.

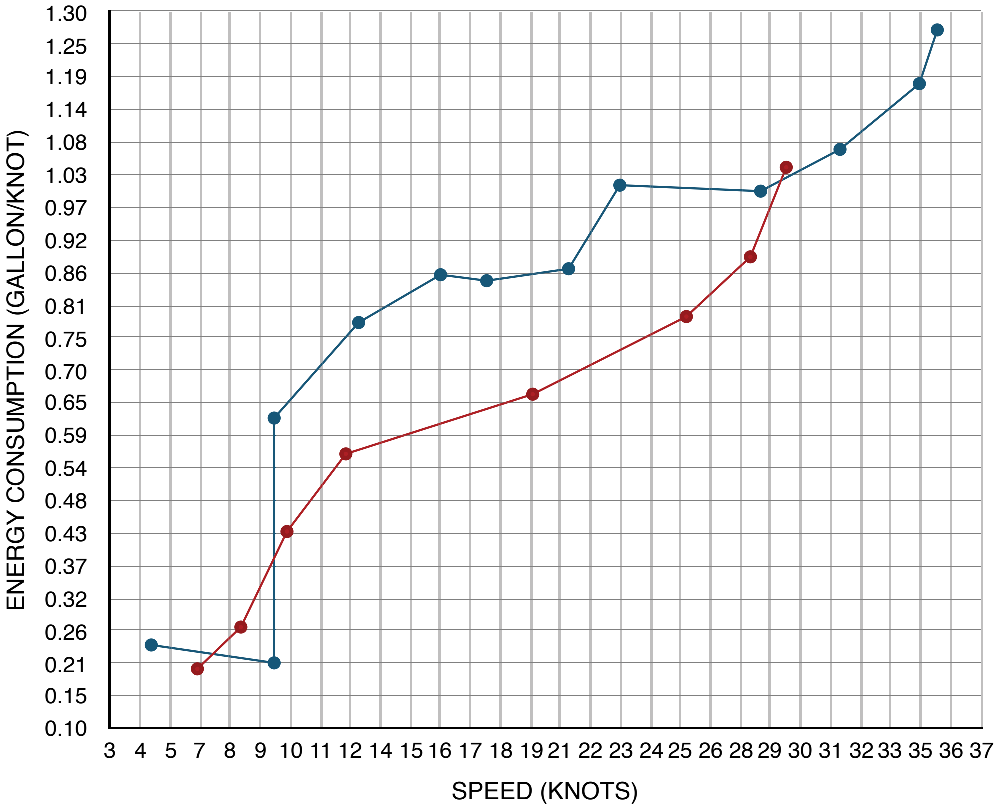
Ellis's first easy planing hull design, built by Bruckmann in 1994, is still in production, a testimony to the durability of the easy planing design concept. But the hull shape has evolved over the seven iterations. Compared to the first easy planing boat, the Abaco 40 has a higher aspect (length to beam) ratio and much higher power to displacement ratio. These design improvements, along with other modifications, allow the Abaco 40 to reach a top end speed of roughly 30 knots, depending upon engine choice, and cruise comfortably in the mid 20's speed range, compared to the mid teen's for the original easy planing single engine boat of similar length.

The need for higher performance easy planing boats has been driven by the increasing top end speed of deep-v boats. Higher top end speed for deep-v boats is creating a wider range of displacement-to-planing transition speeds which, in turn, is increasing the need for, not just easy planing boats but also, higher performance easy planing boats. As a result, easy planing boats are evolving as a larger product segment, positioned between semi-displacement boats and deep-v boats.

Today, there are essentially two forms of easy planing hull shapes with a "downeast" look. The first is Ellis' "Power Chine," which is distinguished by very wide chines at the aft end of the hull. It is these wide chines, together with a flat aft hull shape between the chines, which creates the lift which causes the bow to raise only slightly as the boat climbs its bow wave.

The other downeast easy planing hull is called a "warped hull." Like the Ellis Power Chine, the warped hull has a deep V forward. However, instead of very wide chines aft, the hull of the warped hull morphs from a deep V forward to a very shallow V aft. Both the Ellis Power Chine and warped hull shapes extend the relatively flat aft hull well beyond the transom to create addition lift aft.

Chart 4 - Easy Planing Hull Shape: Abaco 40 vs Warped Hull



	A40	Warped Hull
LOD	39’3”	43’
BEAM	12’9”	14’6”
DRAFT	3’11”	3’
DISP	19,000	23,500
ENGINE	CUMMINS	VOLVO
	QSM 11	D6
	670 HP	2X435HP
DRIVE	PROP/ SKEG	IPS

Which of the two easy planing hull shapes is better? Both have merit. With the same drive system, both will deliver comparable top end performance. However, for a number of reasons, including a more buoyant bow, the Abaco shape is preferable in heavy weather. In addition, only the Ellis Power Chine is built with a skeg protected propulsion system.

Another obvious advantage of the Ellis Power Chine is its ability to drive the boat onto a plane with less power. This lower power requirement is obvious when comparing the performance of the two hull shapes for boats of comparable displacement, shown in Chart 4. Unfortunately, we do not have an exact apples-to apples comparison; the warped hull boat is slightly heavier and substantially wider.

As would be expected, this particular version of the warped hull needs substantially more power than the Ellis Power Chine to initially climb its bow wave; the narrower chines on the warped hull are likely less effective in lifting the bow.

Still another advantage of wide chines is the elimination of the need for stabilizers offered on some competitive boats. The wide chines, together with the skeg, eliminate most rolling in moderate to heavy seas when the wide chined boat is driven to just slightly over displacement speed. Similarly, the extended flat hull makes trim tabs virtually redundant. Both are opportunities to simplify by eliminating equipment and reliance on computers.

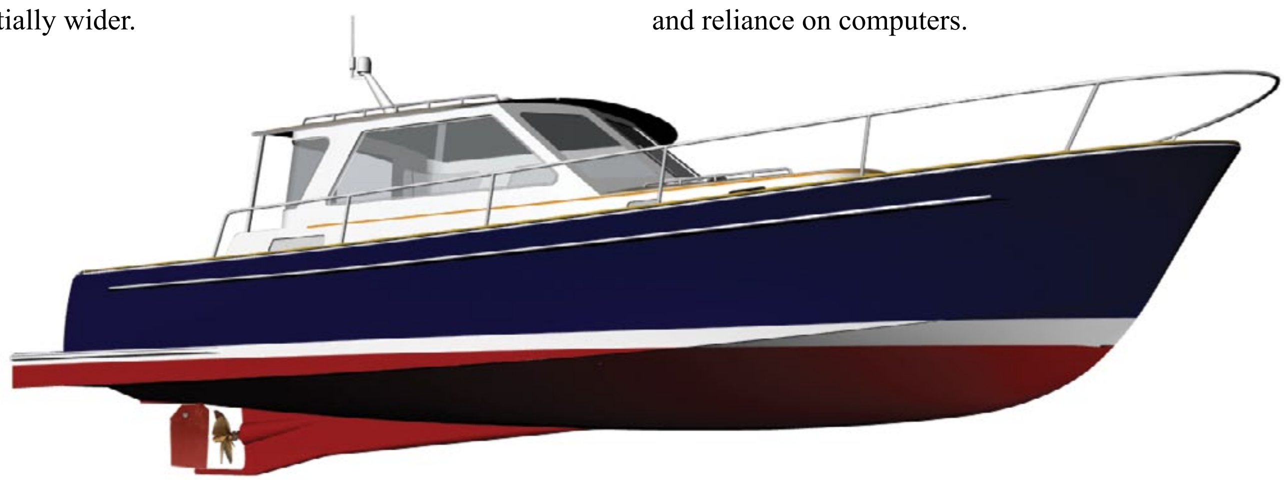
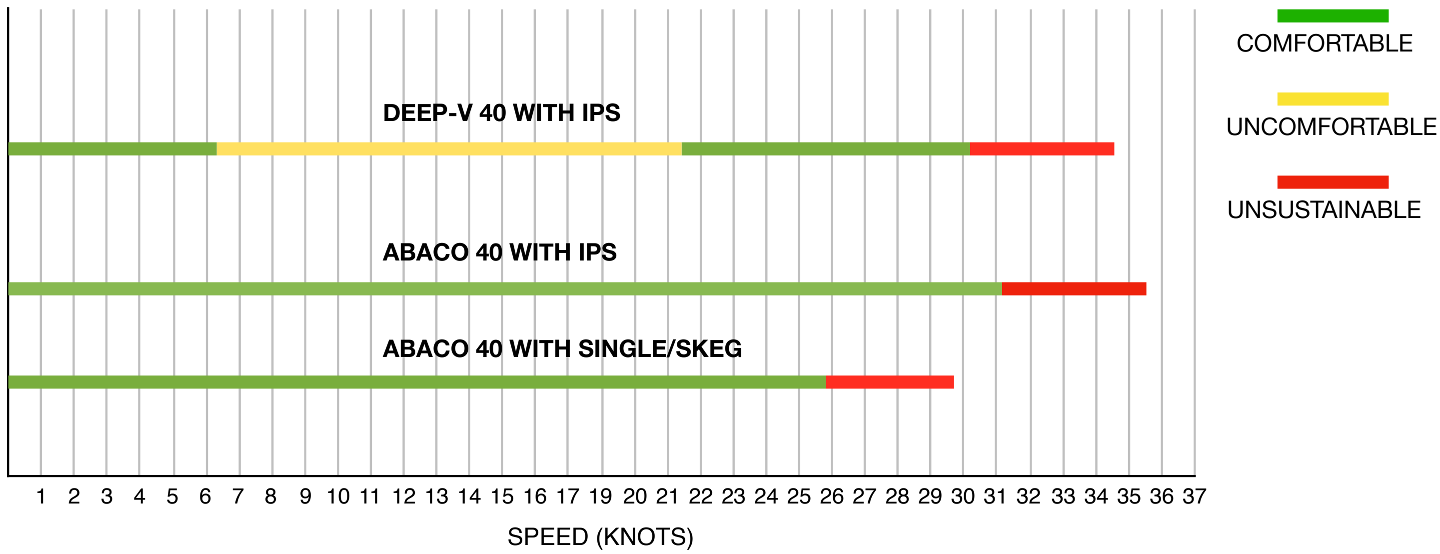


Chart 5 - Comfortable Speed Ranges: Abaco 40 with Single/Skeg or IPS (refer to Chart 3) vs Deep-v 40 (refer to Chart 2)



SPEED

Top end, or wide open throttle speed, is great for selling boats, but, in practice, is a meaningless number. Engines run at wide open throttle quickly burn up. A quick glance at a chart showing engine life relative to engine load shows that most engines should not be run at much more than 80% load for a prolonged period. In fact, the most durable situation is a slow turning engine cruising, not at 80% load, but, at 60% load.

Chart 5 summarizes the comfortable speeds at which a typical deep-v and an Abaco can be driven, assuming fairly flat water. When the wind kicks up, both boats are likely to reduce speed. It is obvious from this chart that the Abaco easy planing hull shape makes a better cruising boat; the range of comfortable cruising speeds is markedly wider. The difference in fuel efficiency, shown in Chart 1, drives home even further the superior cruising characteristics of the Abaco hull shape.

It is instructive to ask the owner of a high speed boat how fast he actually cruises. The common reply is: "Just fast enough to keep the boat on plane. If I go slower, the boat wallows. If I go faster, fuel consumption is too high or the ride is too rough."

Consider the advantages of being able to cruise at any speed - with a safe and reliable drive system.

CONCLUSION

It is very difficult to describe, show on paper or see when looking at an actual hull, the merits of an easy planing hull.

When viewing an Abaco at a boat show, the exceptional workmanship, common sense layout, visibility, protected cockpit, and generous storage areas are obvious. But, without seeing the shape of the hull, it is difficult to appreciate its merits.

In fact, even when seeing the hull, the merits of the shape are only obvious to highly experienced boaters. This may be the reason all of the Abacos sold to date have been purchased by knowledgeable boaters, mostly ex-sailors who are conscious of seaworthiness and familiar with Bruckmann's exceptionally high quality.

For those of us who are not so experienced, the best way to appreciate the merits of an Abaco is to drive one in various seas. It then becomes obvious why the Abaco is the choice of many delivery captains who deliver boats under even bad weather conditions; it's the equivalent of a luxury land rover.

Perhaps the best description of the Abaco hull shape are summed up in Bill Pike's words when he reviewed the Abaco 40 prototype for Power and Motoryacht magazine, the same magazine which included the Abaco 40 among the 25 prettiest boats ever built. Bill called the Abaco's performance "**an almost unheard of feat of hydrodynamics.**"

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ABACO 40 SPECIFICATIONS

LOD	39' 3"
LWL	37'
BEAM	12' 9"
DRAFT	3' 11"
DISPLACEMENT	19,000 lbs.
ENGINE	Cummins 670hp.
FUEL CAPACITY	300 U.S. gallons
WATER CAPACITY	80 U.S. gallons
WASTE	30 U.S. gallons
DESIGNER	Mark Ellis Design

A REAL-LIFE EXAMPLE

In early June 2017, a close friend bought a new high-end 32 foot centre console deep-v, driven by large twin outboards. The boat has a top end speed of about 45 knots. Our friend and his companion, both mature and experienced boaters, ran the boat in wet weather from New England to the Hudson River, up the Hudson to the St. Lawrence River, and up the St. Lawrence to Lake Ontario. The total trip took 9 days, with sleep-overs at the best hotels.

How fast did they run the boat? On the open ocean, with rollers, they averaged 20-23 knots, but beam seas "took the bottom out." On the flat St. Lawrence, they pushed the boat to 28-30 knots for a short period.

They tested the top end speed in flat water, white knuckled, for a few moments.

Between displacement speed and 16-17 knots, the boat threw a huge wake and was impractical.

A recent real-life example that even experienced boaters buy speed, seldom use it and are handicapped at transition speeds.