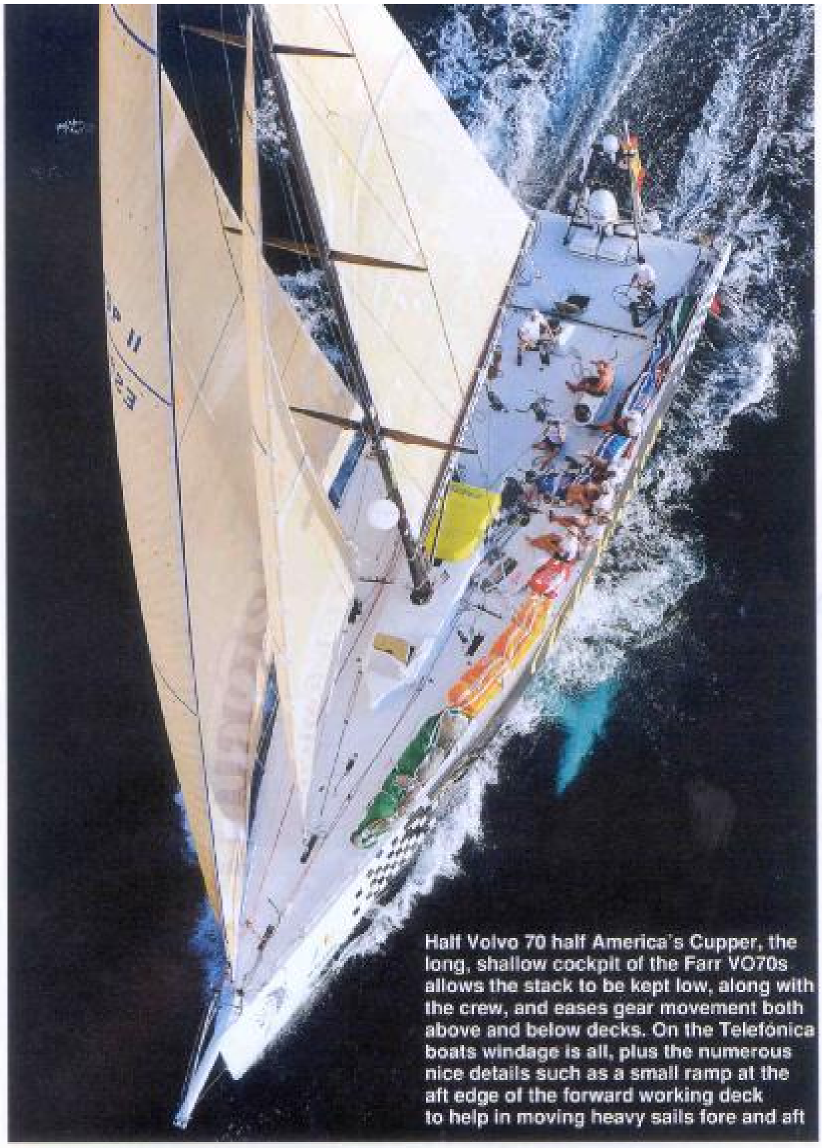
Act two – Part II

In Part II of this look at Volvo Ocean Race development Britton Ward of Farr Yacht Design considers some of the design features of the two Telefónica VO70s and examines some of the initiatives explored by the team's competitors



Half Volvo 70 half America's Cupper, the long, shallow cockpit of the Farr VO70s allows the stack to be kept low, along with the crew, and eases gear movement both above and below decks. On the Telefónica boats windage is all, plus the numerous nice details such as a small ramp at the aft edge of the forward working deck to help in moving heavy sails fore and aft

Same problem... different solutions

One of the most interesting developments of this edition of the Volvo Ocean Race is that it features designs from a number of leading design houses. As a result, each boat exhibits different solutions in almost every area. The hull shapes present some of the most pronounced differences, but appendage sizing and placement, deck layouts, structural design, mast choices and sail inventories also show a wide range of different solutions. In this article we will attempt to provide insight into some of the trade-offs involved in the design of these second-generation VO70s.

Structure, weight and tough sailing

One of the big challenges for designers, builders, shore crew and sailors in the VO70 rule is to hit the narrow weight targets. The all-up weight of the boat now has to be between 13,860kg and 14,000kg – a range of only 1% or 140kg. The maximum permissible keel weight is 7,400kg. The clear target is a maximum-weight keel and a minimum-weight boat. This requires careful design work, detailed weight calculations, continuous monitoring of the build process and thorough control of component weights to present any chance of hitting the bull's eye. Anyone who has experience with this process can testify to the painstaking care necessary to meet weight targets, and to the many ways the effort can be fouled. The Equipo Telefónica recognised the importance of this and Farr Yacht Design remained closely involved throughout the build, commissioning and sailing programme to assist in hitting and maintaining these targets. Published figures show that this effort was rewarded with the lightest boat with the maximum keel weight.

Leg 4 was a new and intriguing leg for the Volvo Race, testing boats in what some of the most experienced sailors described as the worst upwind conditions they had ever seen. Gale force winds, steep seas from wind against current (at least the current was going their way), quickly changing wind strengths – the leg threw everything at the fleet. Designing structures to survive these conditions while meeting the weight targets has proved to be a difficult task.

Telefónica Azul faced the worst of the conditions and came out victorious with very little wear and tear. This boat measured in lightest in fleet with a maximum keel weight and also proved to be the most robust in the trying conditions, which confirmed that it is possible to design a seaworthy boat to an optimised weight. This is a tribute to the builder, shore crew, sailors and designers. The sistership, *Telefónica Negro*, was less fortunate and experienced some localised failures that are still being analysed. The findings will provide additional insight into extreme loading cases.

It is too early for us to have a lot of knowledge of the structures of the boats designed by other design teams; competing camps are reluctant to share such intimate details until much later. However, we have ascertained that the Telefónica twins have more clear area above and below deck to facilitate moving around the sail stack and equipment. This would indicate that they have larger panels and shallower internal framing in some areas aft of the mast.

Forward of the mast we would be surprised if there were significant differences in the main structural layout. With minimum rule panel weights dictating the amount of material in the forward panels, the performance of the panels in adverse conditions is more dependent on careful material selection and laminating. It is also encouraging to see the fleet relatively free from the failures to canting equipment that impacted the last race, indicating some learning in that area!

Hull shape

The most obvious evolution from the





To think that no one considered the chine to be relevant to a modern offshore racer until Marc Lombard first stuck one on his Imoca 60s in 2003… Botin & Carkeek (*Il Mostro, far left top*) and Reichel-Pugh (*Green Dragon, beneath*) also incorporate a second 'virtual' chine near the static waterline where a flat run changes quickly into curved sections, before reverting to slab sides. Also, *Ericsson 3* (*centre top*), *Ericsson 4* and Farr's *Telefónica Black*

previous edition of the Volvo Race is that all the designers have opted for maximum beam on deck to maximise sailing stability and offer the widest possible sheeting angles. Below the sheer line, however, there is a wide range of variation in hull shapes with each design house finding different solutions to the balance between stability and drag for the expected conditions.

By nature of their very light displacement and high beam-to-draft ratio, VO70s are all very straight in profile, but even small amounts of keel spring, or rocker, can impact handling in waves and transitional planing conditions. Performance in high-speed running conditions needs to be balanced against the amount of moderate-speed, flat-water sailing that is expected as these conditions will generally favour straighter boats. With the design of the Telefónica boats we worked hard to provide just enough keel spring to achieve this balance. At the other end of the spectrum most observers would agree that Puma's *Il Mostro* has the straightest keel profile of the fleet with a deeply immersed knuckle. Both Ericsson boats seem to have gravitated to more keel spring than *Delta Lloyd* (their direct predecessor as *ABN One*) and interestingly they both exhibit a concentration in curvature around Station 1 (forward) which may provide for a slight increase in angle of attack and less knuckle immersion.

All the boats have a chine incorporated into the hull shape that allows hull section shapes that maximise form stability within the maximum beam restriction and improve planing performance. There is, however, a range of opinions on the placement and extent of chines across the fleet.

After extensive tank testing and CFD visualisation we opted for a moderate-depth chine at the transom with slight flare in the topsides aft. *Telefónica*'s chine line runs almost parallel to the sheer line and so has a slight upward slope. These chines also fair into the hull section aft of amidships in an effort to avoid drag-inducing crossflow when sailing at high heel angles with the chine immersed. This approach contrasts with the Green Dragon, Team Russia and both Ericsson boats whose chines are more parallel to the waterplane or, in the case of Ericsson, are sloped subtly downward toward the bow.

Both *Il Mostro* and *Team Russia* maintain very deep chines at the transom, which may provide some dynamic stability and effective length at moderate heel angles and may be an effort to achieve enough angle across the chine to throw water away in the same manner as a spray rail on a powerboat. Chine location and effectiveness are clearly an area of diverse opinion and rife for further development and understanding. The optimum positioning and shaping will vary depending on expected sailing heel angles and speeds.

One of the biggest design challenges for high-speed yachts such as the Open 60 and the VO70 is in developing successful means for lifting the bow in high-speed sailing and maximising planing performance, while not overly sacrificing performance in light and moderate conditions. Unlike a powerboat where the thrust is coming from a propeller below the surface with the boat operating mostly in an upright orientation, we are sailing at heel with our driving force being applied by the sailplan a substantial distance above the deck, resulting in a significant bow-down trimming moment. While shifting moveable weight aft and filling ballast tanks help to counteract this, the range of trim adjustment available is only small and additional means need to be explored.

Maintaining a bow-up attitude at speed and heel is an area we have focused on for many years in both our Open 60 and VO70 designs and is most clearly evident in the trim-tab solutions fitted to the Open 60s *Paprec Virbac 2* and *Gitana 80*. It is also one of the factors that has driven us to orient our daggerboards more vertically than most of our design competitors. The VO70 rule does not permit the use of trim tabs or interceptors, so we spent significant effort exploring hull shaping ideas that would provide a good balance between maximising effective length in the predominant moderate conditions while encouraging the bow to lift at speed for planing performance.

After investing some time exploring significantly fuller bow sections and straighter bilge sections we ultimately adopted the use of strakes fitted in the hollows-permitted zone within 7m of the stem. Initially seen as an out-of-the-box idea inspired by powerboats, we fitted a tank model with the strakes and observed a dramatic drag reduction and improved bow-up attitude at speeds above 14kt or so. By speeds of 20kt we were observing total drag reductions of the order of 5-8%! To confirm our results we completed a broader study using RANS CFD simulations that verified the effects observed in the tank and gave us confidence to explore alternative geometries (widths, angles and vertical locations) in CFD before developing the final design.

As always, flat-water CFD or tank testing need to be overlaid with an understanding of the dynamics and added drag that can occur when sailing in waves. These considerations, coupled with an evaluation of the construction weight increases associated with strakes, ultimately led us to a more moderate solution than the large double strakes exhibited on *Team Russia*. The addition of the strakes allowed us to maintain full bow sections above the strake that provide additional buoyancy when punching through waves while permitting a finer entry below the strake that will result in better performance in a short chop. In general, the addition of carefully sized and positioned strakes has been seen as an advantage in both our Open 60 and Volvo 70 work, especially when high-speed reaching.

The other boats exhibit some alternative solutions to these problems. *Ericsson 3* and to a greater extent *Ericsson 4* have very full bow sections, with *Ericsson 4* incorporating a subtle 'chine' through the forebody.

Il Mostro has possibly the finest waterline entry in the fleet, with a deeply immersed knuckle, but her sections fill out quickly above the waterline to provide additional reserve buoyancy and bow lift at heel. Both *Il Mostro* and the Ericsson boats exhibit very straight stern sections with a lot of bilge volume removed below the chine. In *Il Mostro*'s case this is achieved ▷

with what is almost a secondary immersed chine off centreline, while on the Ericsson boats the transition is somewhat smoother.

While the strake option uses the dynamics of the flow around the boat to provide lift to the bow, the removal of bilge volume aft and addition of volume forward rely more on adjustments to hydrostatic and buoyancy distribution at heel in an effort to address similar concerns.

Appendages

Looking at the fleet on the hard it will be apparent to most observers that there is a wide range of opinions on appendage sizing and placement. Smaller rudders will have reduced viscous drag and will allow the weather rudder to lift clear of the water at a lower heel angle, reducing the surface-piercing drag, but this must be balanced against the added control and steering reserves available from a larger foil. Testing in the Mediterranean on the old *Brasil One* before the race may have guided our own team to a rudder sizing a little on the lean side for the confused downwind seas conditions of the Southern Ocean. This issue is currently being addressed by the campaign; larger rudders were trialled on *Telefónica Negro* on Leg 4 and further adjustments in blade size are forthcoming.

Daggerboards present another area of substantial variation in sizing and positioning. Being cambered asymmetric sections, the loading of the daggerboard can be achieved by a longer chord foil with less camber or a shorter chord, but with more heavily cambered sections.

Incline or cant of the board can also be adjusted to influence the line of action of the daggerboard loads. Similar to our Imoca 60 designs, our VO70 boards are more vertically oriented at typical heel angles than those of the rest of the fleet. The more vertical angle does produce some induced and junction drag penalty, but it allows the board to generate an (upwards) vertical force component at typical heel angles that serves to counteract some of the downward sail forces and can assist in lifting the bow. Positioning of the boards longitudinally is also directly related to the yaw balance solution for the boat and tied directly to maintaining reasonable rudder loads; as such, daggerboard loading and placement are directly tied to the rig placement and rudder size. The Telefónica boards are located just forward of the mast and positioned and sized to allow clearance with the bulb when canted – a primary constraint on the board depth.

Puma's *Il Mostro* would appear to have some of the largest daggerboards in the fleet both in terms of chord and span, but again the board lift generation capacity is closely linked to section camber as well as plan form area so it is hard to make any firm observations in this regard. Similarly, judging the draft of the boards is also difficult as each team has freedom in selecting their board support systems. Interestingly, *Ericsson 3* and especially *4* have some of the smallest daggerboards in the fleet and are also located the furthest forward. In the case of *Ericsson 4* her boards are also well inboard compared to other boats.

One of the more unusual features of the Telefónica daggerboards is the tapered tips that result in an improved spanwise lift distribution, reducing induced drag and achieving a higher centre of pressure to reduce hydrodynamic roll moment. By optimising the section shapes along the board this also allows an improved section shape more suitable for the lower load requirements of partial-board reaching conditions. To avoid intersection drag issues and problems with large gaps around the board when partly lifted we developed a guillotine door system that seals the holes when these tapered boards are retracted.

Deck layout

While the remainder of the VO70 fleet have embraced deck layouts that are conceptually similar to boats from the previous generation, we have opted to take a very different tack with a shallow, full-width open cockpit that extends forward to the companionway. This arrangement has been the source of much discussion in various forums with some arguing it is unsafe while others proclaiming it a huge breakthrough and a big safety improvement for anyone working on deck, especially to leeward. The adoption of the open cockpit arrangement is a new development for version 2.0 of the Volvo 70 rule that now explicitly specifies that the cockpit must drain at up to 35° of heel. In the previous version of the rule this was more ambiguous as it required cockpit drainage at 'typical sailing heel angles'.

From a design and sailing perspective there are a lot of advantages to this

Top left: _Il Mostro_ features the flattest keel profile of this year's VO70 fleet, as well as a full upper bow for buoyancy which snubs on deck, similar to the very full bow on Juan Kouyoumdjian's _Ericsson 4 (lower far left)_. However, on _Ericsson_ the fullness is maintained down to the stem – along with slightly more rocker than the Puma VO70. Note the subtle, low wetted surface quasi curved-chine forward on _Ericsson 4_, which Juan K has opted for in preference to the use of either bow strakes or rails

arrangement. The cockpit is shallower than those of most other boats to allow more storage volume below decks, but the net effect of removing the side decks and cockpit side walls and lowering the jib tracks to the cockpit sole is a significant vertical centre of gravity improvement. Locating the primary and secondary winches onto isolated winch-pods created clear access for the sail stack to be situated on the cockpit sole, lowering its centre of gravity while the pods help secure the stack as far outboard as possible. Moving the stack during manoeuvres is also eased by having it at a single level and by the presence of a ramp at the forward edge of the cockpit to ease the fore and aft movement of sails.

The stacked sails now sit predominantly below the sheer line, so windage drag is reduced and as a benefit they provide a comfortable place for the crew and trimmers to sit that maintains their centre of gravity as far outboard as possible but also keeps the crew well below the limits of the lifelines. Safety has been improved drastically for crew working to leeward on these boats by having the lifelines at chest height rather than knee high as in more traditional cockpits.

Compared to the rest of the fleet our deckhouse may not be the most aesthetically pleasing but conforms to the rule-required heights in the smallest planform possible. Line tunnels and penetrations through the house are largely avoided which helps minimise water ingress. The forward end of the house is shaped to shed green water away from the boat, although given the substantial amount of green water these boats see it is at best an incremental improvement! While many of the other boats exhibit a significant amount of camber in their decks we have opted for minimal camber, reasoning that the rule-required structural scantlings provide sufficient longitudinal stiffness and the lower centre of gravity achieved with the flatter deck and lower deck hardware was a benefit worth pursuing.

Spars and rigging

Significant developments in the spar and rigging areas have occurred with this generation of VO70s. The masts are from a number of different designers and manufacturers. Southern Spars rigs are fitted to the Ericsson boats, Puma, Green Dragon and Delta Lloyd, while Hall Spars USA provided the rig for Team Russia. Most of the teams have adopted Southern Spars' EC6+ continuous carbon rigging with the exception of Team Russia which is fitted with Future Fibres' PBO rigging.

The Telefónica programme worked closely with Scott Ferguson and Hall Spars Holland in the design and construction of the masts. With the version 2.0 rule allowing the use of high-modulus carbon in the mast and a conservative minimum mast weight requirement, it became possible to consider some alternative rigging arrangements. Analysis indicated that sufficient topmast stability could be achieved without the use of topmast jumper struts and their supporting stays, offering significant windage drag reductions. Additionally, the lack of jumper struts reduces the possibility of tearing a sail during manoeuvres, which is of particular concern in the short course inshore racing. After testing our initial jumperless rig on the VO70 *Brasil One* a number of refinements were made to the stiffness distribution of the spar, but in general the concept has worked very successfully to date.

Interestingly, compared to the other boats in the fleet our rig also appears to be the smallest in chord length, which should provide additional windage gains.

Increased mast stiffness has also allowed for some novel backstay solutions. A typical arrangement utilises a pair of topmast backstays, a pair of runners and two pairs of checkstays. The Ericsson boats remove one pair of checkstays and use a deflector from the runner in place of an upper checkstay. Our Telefónica rigs have only two pairs of running backstays, with a deflector on the topmast stay at the hounds to combine the topmast and runners into one pair of running backstays. By eliminating a pair of backstays a sizeable windage reduction is achieved.

Observers with an eye for detail will note that the Telefónica rigs flare out on the front face at the measurement datum band. This is the point from which J is measured and so the addition of the 'bump' gives us a gain in effective headsail area. This is compounded when the effect of the 'bow pyramid' is included, which shifts the intersection of the deck and the forestay up thereby increasing the distance between the shroud plane and the forestay. This allows for a larger LP on J2/3 headsails which closes the area gap between the non-overlapping headsails and overlapping J1 headsails.

Conclusion

Volvo Open 70s are unquestionably among the highest-performing boats afloat. They can achieve astounding speeds and, as seen in the last leg, will encounter some of the worst conditions imaginable. The dynamic nature of VO70 sailing clearly rewards sailing skill and seamanship with significant performance gains, perhaps more so than in heavy fixed-keeled boats. Our task as designers is to seek out a performance edge, and it was our goal to look at every area of the boat in an effort to provide our sailing team with the best platforms possible for the race. Similarly, all the other design teams have produced their own different interpretations of the optimum VO70, each with its own unique features and design choices. The results make for fascinating study. ❑