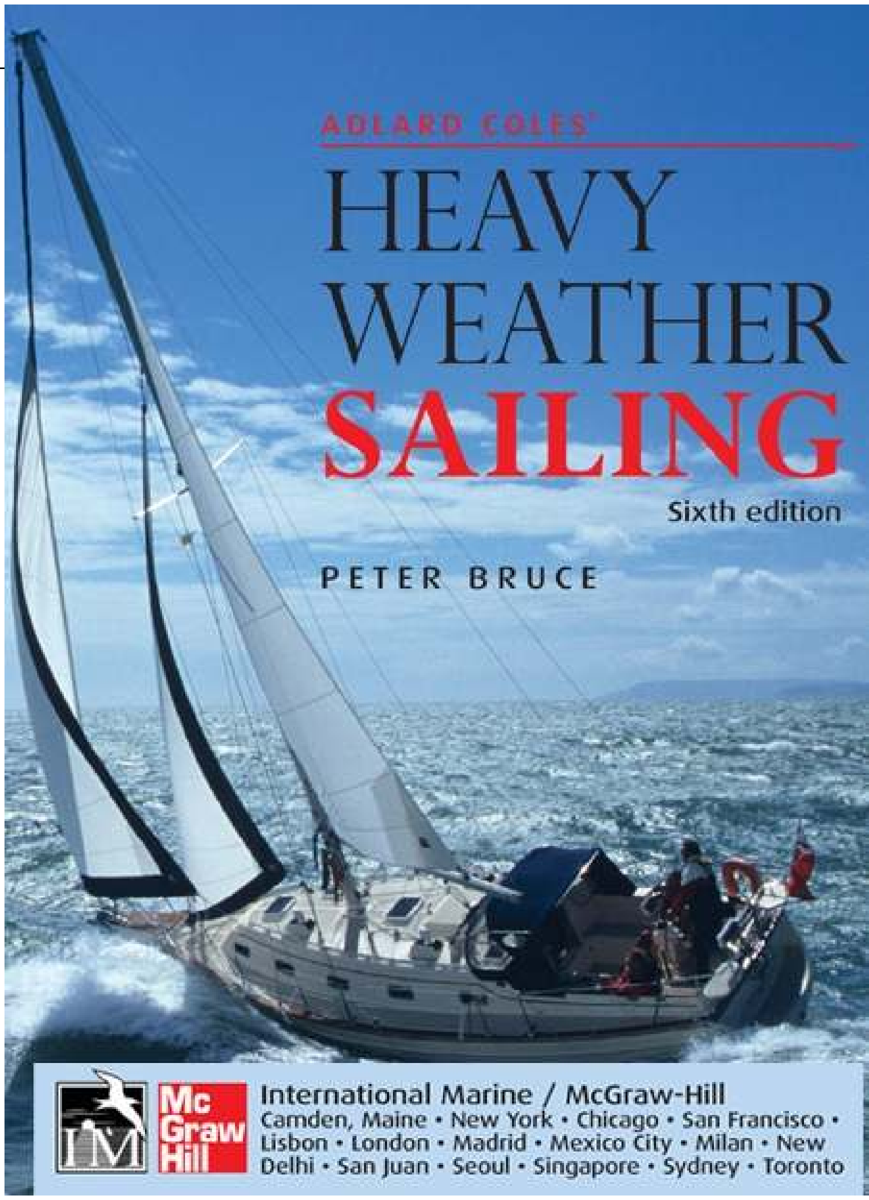
ADLARD COLES'
HEAVY
WEATHER
SAILING
Sixth edition
PETER BRUCE
International Marine / McGraw-Hill
Camden, Maine • New York • Chicago • San Francisco •
Lisbon • London • Madrid • Mexico City • Milan • New
Delhi • San Juan • Seoul • Singapore • Sydney • Toronto

Contents


CORK PILOT

Acknowledgements

Through Adlard Coles, *Heavy Weather Sailing* became such a respected source of yachting information worldwide that it would have been a formidable task for any normal person to carry out the task of updating it single-handed. I have sought the most eminent and wise counsel that I could find to help me with the task, and have had the script read by as many yachtsmen of scholarship and long experience as possible. Once again I owe much to others in the compilation of the sixth edition o *Heavy Weather Sailing*.

Again Sandy Watson, a member of the Royal Cruising Club, has patiently given up much of his time to reading the script and advising on format, aided significantly by his wife Winki and daughter Sarah. After years of noble proof-reading, Leonard Wesson has gone into well-earned retirement, but happily his place has been taken by Dr Ross Coles, son of Adlard. It is a splendid thing that a membe of the Coles family should be so closely and constructively connected to the book again and I am mo grateful to him for his painstaking work and sensible suggestions. Other readers who have been of great help are David Hughes, Michael Pocock, Michael Thoyts, Simon Wilkinson, David Wagstaff, Alex Whitworth, Michael Derrick, David Hughes and David Dale. I have also received gallant suppor from James Beattie, Richard Clifford, Russ Kerslake, David Wagstaff and Robin Leuchars in respect of the parachute sea anchor and drag device trials.

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Olin J Stephens II, who must rate highly amongst the most admired yacht designers in living memory, and whose yachts remain ever famous for their good looks, speed and remarkable sea-keeping qualities.

Andrew Claughton, once from the Wolfson Unit for Marine Technology, Southampton, but now wit the United Kingdom America's Cup group as Design Team Coordinator, whose chapter enables comparisons to be made between design characteristics of yachts in a way that was previously only achieved by subjective means.

Matthew Sheahan, a highly experienced yachtsman who currently writes for *Yachting World*, and used to work for a leading British mast manufacturer. His book *Sailing Rigs and Spars* was a perceptive contribution to a subject not so often written about, and his chapter in *Heavy Weather Sailing* is a masterly exposition in the same theme.

Richard Ebling, a meteorologist for 41 years who has, for the past 20 years, been providing weather information to the Royal Ocean Racing Club for all its major events and been a member of their Rac Team. His chapter on the meteorology of heavy weather takes weather forecasting a step further than most books on the subject.

Dr Sheldon Bacon, from the Southampton Oceanography Centre, has put a new angle on the subject of waves, which is likely to be understood and appreciated by people who, like him, enjoy small boat sailing. He has also responded to an intermittent maze of questions that he answers patiently and carefully and has steadfastly maintained a scientific approach in the face of numerous media revelations.

Hugo Montgomery Swan, editor of the *RIB International* magazine whose offshore feats have astounded other ocean RIB drivers. His assistance with photographs has been of tremendous help.

Dag Pike, rightly famous for racing across the Atlantic in powerboats and rightly famous for a mul~~titude of powerboat books he has written that are based on a lifetime of powerboat experienc~~e an acute observation.

Professor Noel Dilly, a professor of medicine, who writes on the subject of seasickness in the most comprehensive manner, but who also has been a source of valuable information on the subject of series drogues, which he has tested from his own small yacht. **Mark Orr**, Joint Editor of the magazi *Multihull* amongst many other diverse pursuits. His chapter is based on practical experience, as well as that of his large number of readers. **Richard Clifford**, who has sailed worldwide all his life and often single-handed. For example he has crossed the Atlantic seven times, including three single-handed races east to west and has recently sailed out to Australia mostly single-handed. He must ran as one of the tougher and more nimble sailors on the planet and his practical assistance and advice with drag device trials has been most welcome.

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Foreword by Ellen MacArthur

During my round the world record attempt, sailing through the end of the Southern Ocean in January 2005 was horrendous. We had a big depression coming through and the winds were 80 knots on the back side of it which, if you're in that, you're probably not going to survive. You have to stay in fron of it, so the pressure to maintain a very high speed in extremely rough conditions was really stressful If you break something, in six hours you're going to be in a cauldron.

I experienced icebergs, swells, pounding hailstorms and waves that were so long, it was like looking across a valley. For three days and nights the wind was so strong that the boat was in danger of going over – like being on a tube train running out of control! I had to take sleep in 10-minute snatches and the effort just to keep standing upright was draining, let alone having to climb the 100ft mast to make repairs, which I had to do twice. It was like trying to hang on to a telegraph pole in an earthquake. You get beaten up black and blue. The biggest risk isn't falling, although there is a risk o that – it's breaking an arm or a leg as you slam against the mast…

…but there is nobody forcing me to do this, so why do I do it?

Yes, I do find myself in some challenging situations, but that is one of the reasons I am compelle to keep going back for more. The Southern Ocean is one of the most powerful and desolate places on the planet, but with the wind, rain and mountainous seas comes great beauty and a unique experience of nature in its rawest form; although a harsh environment to be in, it is one that I have been very privileged to witness.

The oceans can be an unforgiving and unpredictable place, but therein also lies the excitement. Potentially, sailing solo round the world can be a dangerous challenge, but we do everything we can t make the boat as safe as possible and ensure that all the safety procedures are in place should the worst happen. It is crucial to be aware of the risks and have a fundamental understanding of the environment and the challenge you are about to undertake. Ultimately, the risks we take are calculated: I work with the weather analysts to examine the weather ahead of me; I study every aspec of the boat. Knowing that you have covered all you can and learnt all you can on the land before you leave helps to prepare you mentally, but you also have to be prepared for the possibility that some things will be out of your hands – the weather, a breakage onboard. When you are out there, if something breaks you're the one that has to fix it, so it is vitally important that you know the boat inside out.

Ellen MacArth

Preface

Adlard Coles OBE died in 1985. He left behind him a multitude of friends and admirers, many of whom knew him only through his books. Apart from his ability to write vividly and clearly, Adlard was an extraordinary man. In spite of being a diabetic, a quiet and very gentle person with something of a poet's eye, he was incredibly tough, courageous and determined. Thus it was very often that Adlard's *Cohoe* appeared at the top of the lists after a really stormy race. When reading Adlard's enchanting prose one also needs to take into account that he was supremely modest, and his scant reference to some major achievement belies the effort that must have been required. It is clear that Adlard minimized everything, which does him credit. As an example, the wind strengths he gave in his own accounts in the earlier editions of *Heavy Weather Sailing* were manifestly objective and warrant no risk of being accused of exaggeration for narrative effect.

There were three editions of *Heavy Weather Sailing* undertaken by Adlard Coles and this new edition of *Heavy Weather Sailing* is my third, and brings the total number of editions to 6 over a span of 40 years. This is a record that the Coles and Bruce families, who have often sailed and worked together since 1950, can be proud of. Indeed Ross Coles, Adlard Coles' son, has been closely associated with the production of this new edition.

In writing about a subject that most people do their best to avoid, it should be remembered that to have successfully sailed through a particularly violent storm gives a sailor confidence at sea as nothing else will. Adlard Coles lightly referred to the collection of storms that he endured as being like trophies of a big game hunter, but they are educational and character forming too. After a big storm it will be easier to judge how much a boat and crew can endure before they break, and what the warning signs are.

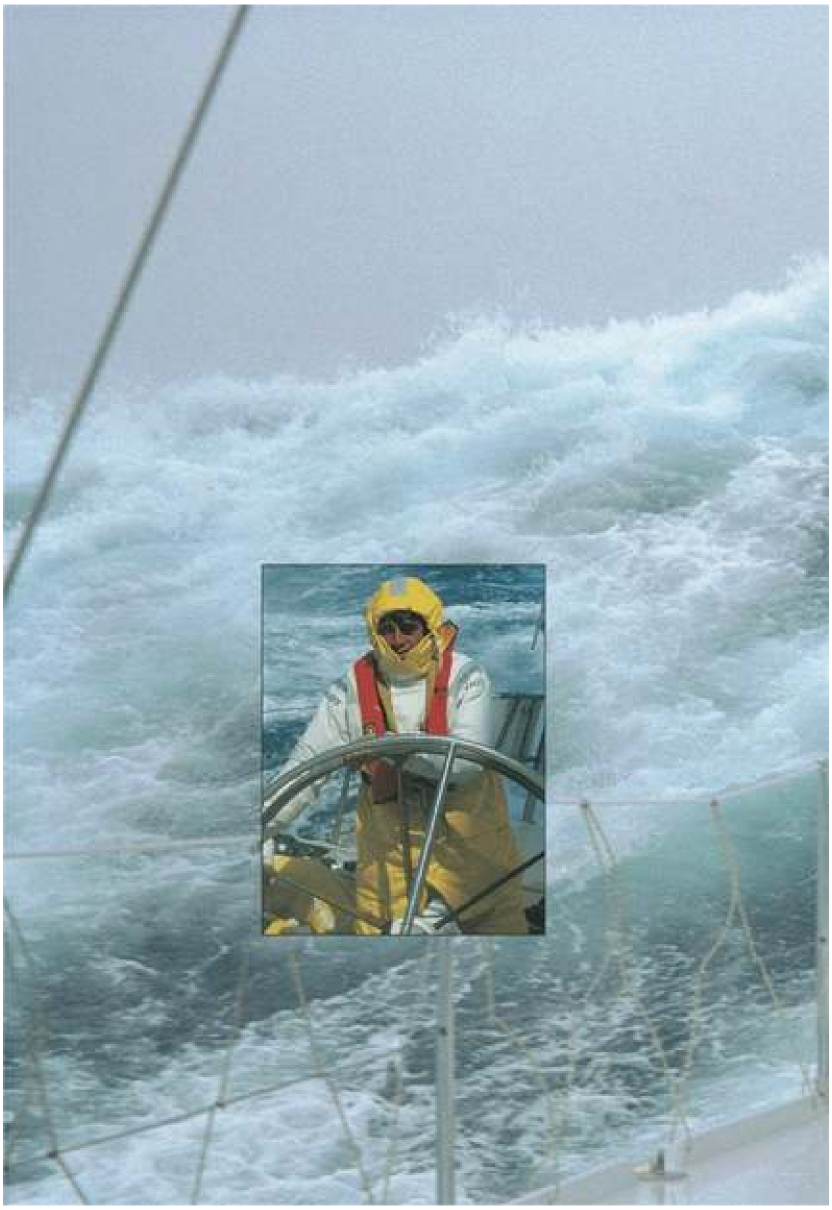
The ethos of this book is to supply the specialist information that will prepare a sailor for heavy weather, and give honest examples of what happened to people and their vessels that have encountered a severe storm. Most space has been given to the specialist information – the expert advice; as this provides a platform of knowledge to enable the reader to be able to glean the maximum from the storm experiences that follow, and the principles to employ when bad weather approaches. These storm experiences have been carefully picked to cover a wide range of predicaments. They tend to relate to unusually high wind strengths because these rare extreme conditions best prove the worth of a particular course of action. They also illustrate how modern heavy weather seamanship has been able to evolve with the benefit of improved knowledge, clothing, design and materials. The improved knowledge is the most important factor, of course, and the contributors of these accounts have freely given of their experience to help others who may follow in their wake.

Certain storms have become famous, not only because they were storms of remarkable strength but also because they affected a large number of people and were in a position to receive wide media coverage. Amongst the most famous of these was the Fastnet Race of 1979. This storm has been widely publicised, and the time has come to omit the detailed account from this new edition to allow for new sections. The Santander race of 1948, has been retained to keep the connection with *Heavy Weather Sailing's* legendary original author, and to demonstrate the similarities and contrasts of previous years.

One third of this edition is completely new, and many of the illustrations are new. Material retained from the previous edition of *Heavy Weather Sailing* has been thoroughly revised where appropriate.

PART ONE

EXPERT ADVICE



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Yacht design and construction for heavy weather

OLIN STEPHENS

HEAVY WEATHER HAS TAKEN ITS TOLL among vessels of all the shapes and sizes that one can imagine, and the survivors have been just as varied. Is it worthwhile, then, to consider the design characteristics of yachts that should best survive the worst that weather can offer; or is handling the only factor? It seems clear that the boat counts too, and could be decisive, although once at sea, the action of the crew is what counts.

To declare the obvious, to survive means to stay afloat, to keep water out of the hull; and further t remain in, or at worst return to, an upright condition. Strength and range of positive stability are first requirements. In the course of this study we shall try to determine how these essentials can best be refined and combined with other characteristics to provide for the safety and comfort of the offshore crew.

A lifetime around the water has shown me the many types of yacht that have come through the extremes of weather on long cruises. I think it must have been in 1926 when my brother Rod and I spotted Harry Pigeon's *Islander* lying in New Rochelle harbour, not far from our home. We were quick to greet him from a borrowed dinghy and to take him for a tour of the nearby countryside after inspecting the home-built 10.4m (34ft) yawl that he had sailed singlehanded around the world. Neithe *Islander's* light displacement nor simple vee bottom form made for survival difficulties. One was most impressed by the simplicity of the construction and equipment: no engine or electrics of any kind, no speedometer, or even a patent log. We admired the man who made it all seem so easy. Soon we heard that Alain Gerbault and his *Firebird* were at City Island, so we went there. The contrast was in every way disappointing, but the older, heavier boat had made it through some very bad weather.

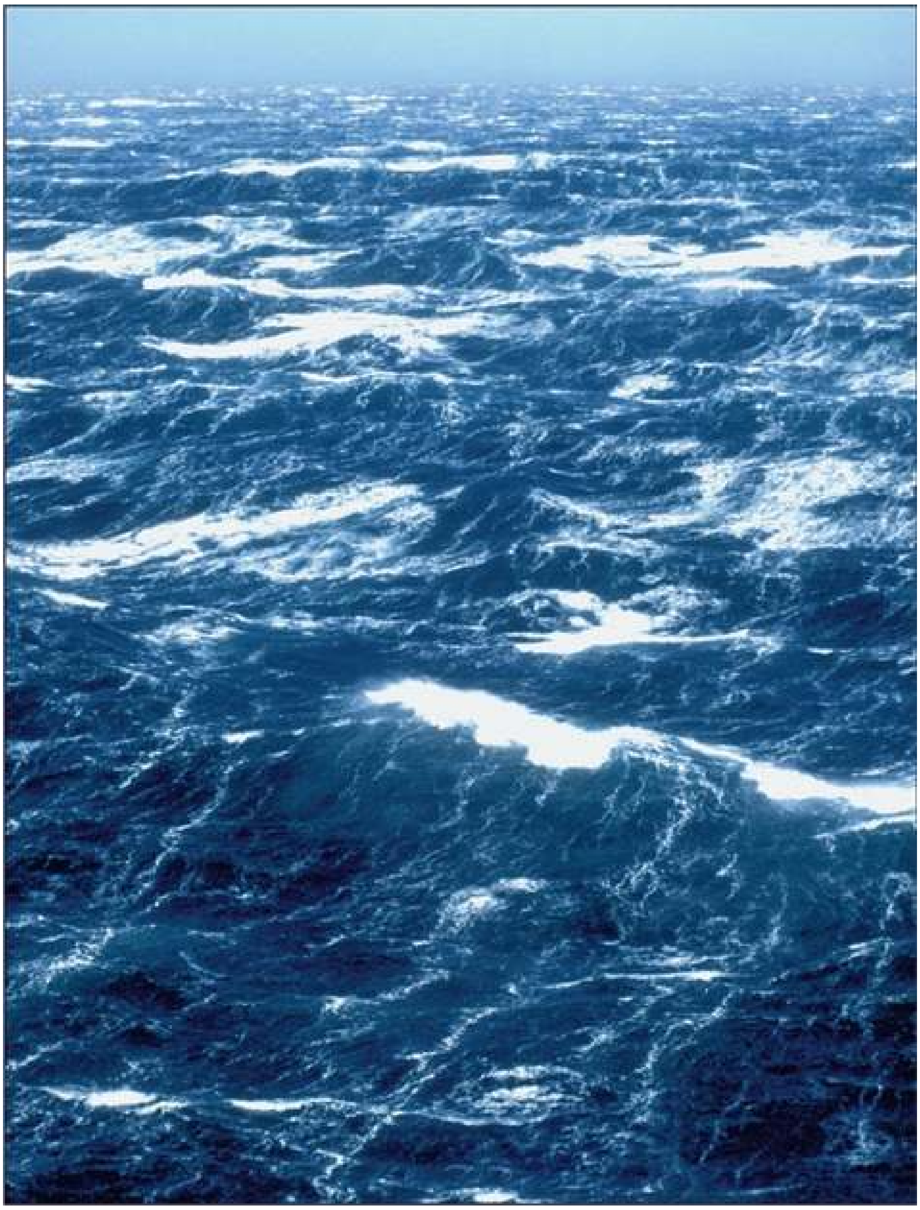
I had, and retain, a great deal of respect for the work of Dr Claud Worth, the owner, during the 1920s, of several yachts called *Tern*. He must have been a thorough and meticulous student, as well a a practitioner, of offshore sailing. He advocated moderate beam, plenty of displacement and a long keel. I read and re-read his books: *Yacht Cruising* and *Yacht Navigation and Voyaging*.

This background, reinforced over the years, had led me to believe that size and shape can vary widely though I like to avoid extremes. If structure and handling are sound, then the larger the better but the bigger vessel demands more of the builder and crew as the loads increase geometrically with size. Big sails supported by great stability require strength and skill to control; small sails can be manhandled. Similar observations apply to hull, spars and rigging.

Analytical studies, such as those carried out in the course of the joint United States Yacht Racing Union (USYRU) and the Society of Naval Architects and Marine Engineers (SNAME) study on Safet from Capsizing, and by the Wolfson Unit of the University of Southampton, have noted two characteristic conditions of capsize that have a bearing on design, ie those that occur due to the force of the wind on the rig, and those resulting from the jet-like force of a breaking sea. In the first condition the light structure of a small boat may not be overloaded, but in the second the hull or deck may be smashed, destroying its ability to float like a bottle.

As the terms are often used, size and displacement mean about the same thing, although the terms 'light' or 'heavy' displacement usually refer to the displacement/length ratio, expressed as tons of displacement divided by the cube of 1 per cent of waterline length in feet. Though extreme, one can accept a range of 500 to 50 in that ratio over a range of 6–24m (20-80ft) in waterline length. In geometrically similar hulls the righting moments increase in proportion to the fourth power of length while the heeling moment grows only as length cubed. Because of this, small boat designs need more inherent power, ie beam and displacement, while big yachts with similar proportions need very large rigs. Thus smaller boats should avoid the bottom of this range and the larger boats should avoid the top. Figs 1.1 and 1.2 show a possibly over-liberal suggested range. I say 'possibly over-liberal' with the personal feeling that the area just below the middle of the suggested range, say 125 to 250 in the same length range, is best of all.

Yachts should be designed and built to withstand extreme weather, even as severe as in this photograph of the South Atlantic when wave height was estimated at between 12 and 15m (39 and 49ft), and wind speed between 60 and 80 knots. *Photo: Christian Février/Bluegreen*



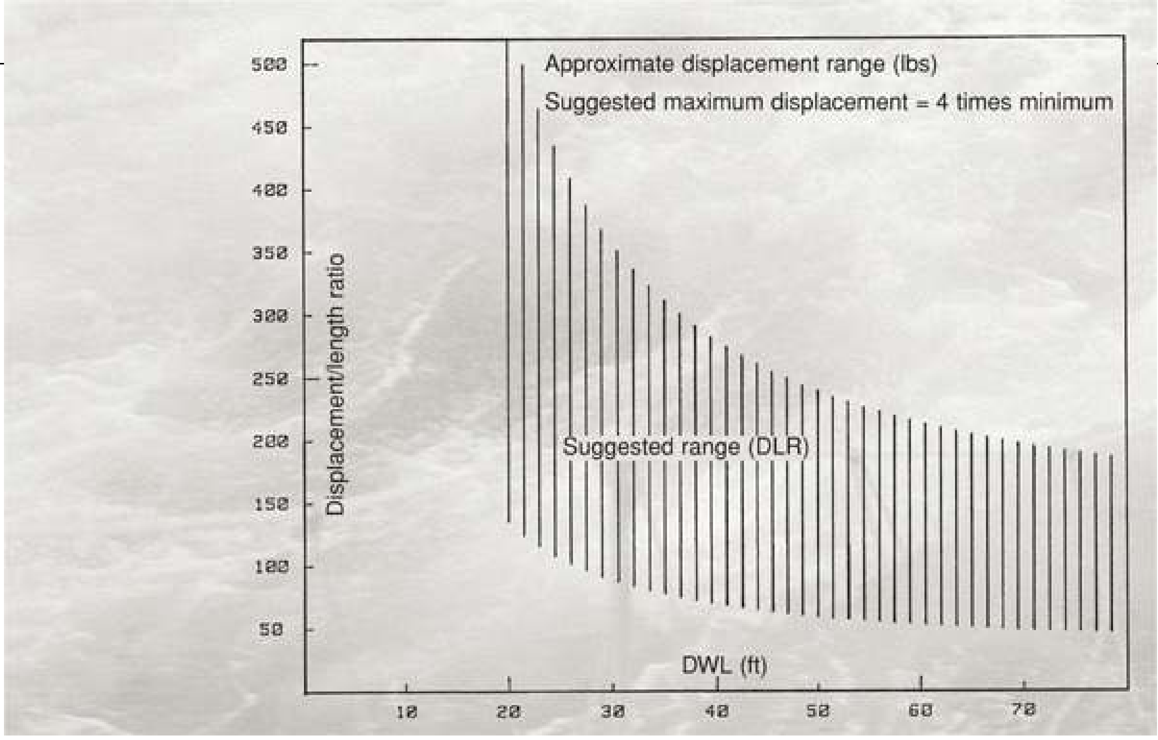


Figure 1.1 Suggested range of displacement/length ratios for a given waterline length.

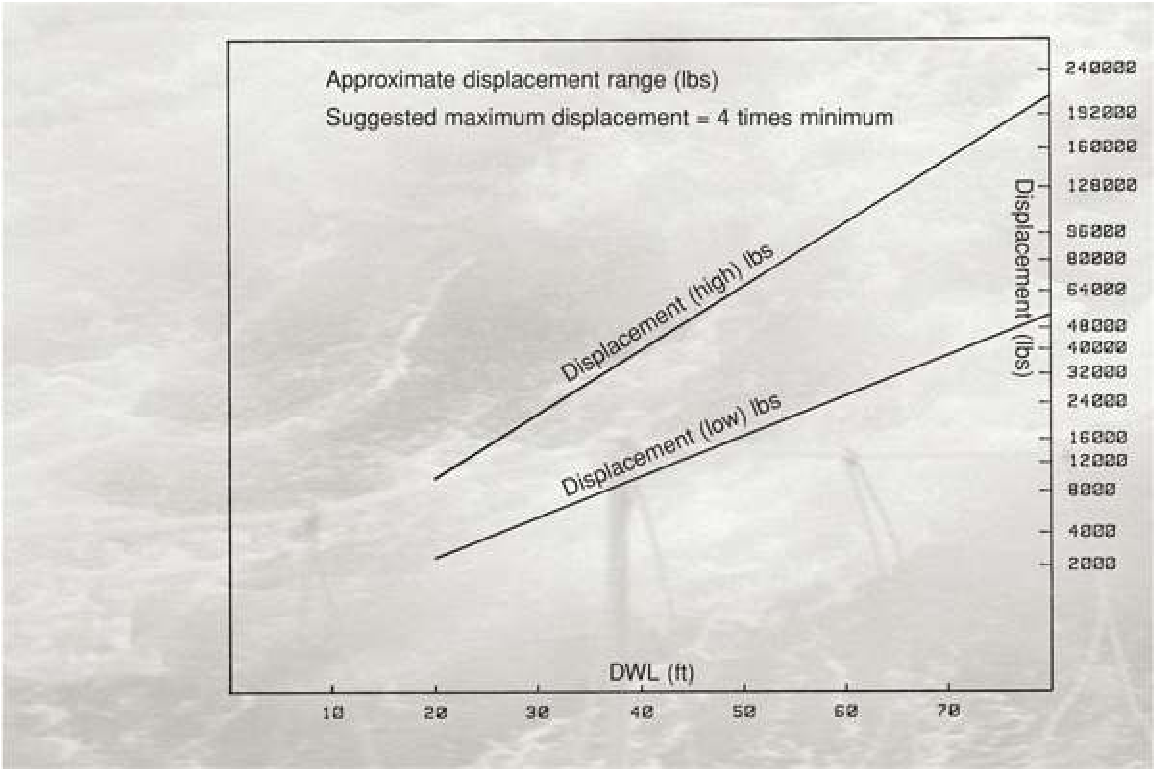


Figure 1.2 Suggested range of displacement range for a given waterline length.

Displacement is determined primarily by the requirements of strength and stability and, further, for comfort in the sense of motion and of roominess. The yacht's total weight must provide for an adequate structure together with the weight of crew, stores and equipment, and for sufficient ballast t ensure stability for sail carrying power and a good range of positive stability. Truly efficient use of th best materials can give a light hull and rig and, with enough ballast, appropriate design can provide stability, adding up to a lower limit on safe displacement. Though structural materials are not the subjects of this study it should be said that, in the hands of a competent builder, sound light hulls can be built of many different materials including wood, GRP and aluminium alloy. The high-strength, high-modulus materials often used as composites, such as carbon fibre, offer, when used with care ar experience, strength and light weight. Steel and concrete are inherently heavier, especially the latter. Boats with light displacement must have light hulls so as to carry a reasonable amount of ballast for the sake of stability. In heavier boats material selection is less critical.

The vertical centre of gravity and hull geometry combine to establish the range of positive stability. A good range, for illustration's sake, over 120° at least, will virtually assure that a capsized boat will right herself in conditions that have caused a capsize. Much lower values may ensure the reverse. The determination of range depends on a calculation that may be more or less complete in it application to deck structures, cockpits and allowance for some flooding. It also depends on the existing centre of gravity as affected by sails such as those that are roller furled. This suggests the need for some allowance over a stated minimum. It seems unfortunate that racing influences, earlier on the IOR, and still, although to a lesser degree, the IMS, have led to wide beam, and a shoal body: the conditions for a poor range. At least the IMS rule favours hulls with a low centre of gravity, a better situation than the IOR which encouraged an unwholesomely high centre of gravity. Ballasted narrow, deep hulls of the older International Rule type like a decked over 12 metre could go to 180°, representing the full 360° rollover. In beam and hull depth moderation is the best course. Beam offer initial stability and roominess, but too much of it reduces the range of positive stability and results in quick motion. Depth provides easier motion, headroom, structural continuity and space for some bilg water; all desirable, but they are less conducive to high speed. Heavy ballast contributes to range of stability, but also gives quick motion.

A moderate ratio of beam to hull depth seems ideal; say, a beam of not more than three to four times the hull body depth, with the centre of gravity low enough to give a positive stability range of a least 130°. Here one may note that Adlard Coles' three *Cohoes* fall within the range of proportions that I have recommended. Also, that the damage to *Vertue XXXV*, described in earlier versions of *Heavy Weather Sailing*, was caused by a breaking sea that threw her over and down, smashing the lee side of her cabin trunk (coachroof), a vulnerable structure at best, due to structural discontinuity. The *Vertue's* small size probably did not permit the incorporation of the material needed for greater strength. A similar occurrence was the damage to *Puffin*, one of my own designs and not quite so small, but hit hard at a weak point. *Sayula's* survival, after a severe knockdown in the Whitbread Rac of 1973, with great discomfort but minimal damage, contributes to confidence in the larger boat.

The danger of weakness should not be seen as condemnation of the coachroof, which is often needed to provide headroom and can also contribute usefully to range of stability by virtue of its volume if the hull is free of water. It is simply a reminder that all corners or abrupt discontinuities of area in a structure can be sources of weakness, and should be carefully designed and built.

It must be clear to many observers that the trend to keels that are very thin or narrow at the hull juncture weakens an already highly loaded spot by raising even higher the loads in that area, and in turn the stress in keelbolts, the keel and the associated hull structure. Whenever a narrow base is used the structure must be most carefully considered.

The power to carry sail is quite different from stability range. A naval architect evaluates both at small heel angles by measuring the vertical span between the centre of gravity and the metacentre where, at a small heel angle, a vertical line through the centre of buoyancy cuts the heeled centre plane. The product of this height and the tangent (a trigonometrical function) of the heel angle gives the righting arm at small angles which, multiplied by the displacement, gives the righting moment. The displacement is constant, but with increasing heel the righting moment is strongly dependent on hull shape, varying with the heel angle and the ratio of beam-to-hull body depth. A beamy shoal-bodied boat will have great upright metacentric height without implying a large heeled righting moment that will have been lost with increasing heel when the righting arm shrinks and becomes neg~~ative. Good proportions between beam and hull depth will hold that factor almost constant u~~p to angles of 35–40°, while assuring a safe range of positive stability. The first example will feel stiff, bu must be kept upright to use the power of the rig, while the deeper boat can benefit from plenty of sail power up to a large heel angle. The beamy, light type depends greatly on crew weight to minimize heel so as to maintain sail power and speed.

Comfort is another characteristic related to beam. Over-generous beam contributes roomy space below, but tends to quicken the vessel’s motion and reduce the stability range. While this is not the place to discuss arrangement plans, reference to the importance of air without water in the cabin does relate to safety through the crew’s ability to perform. I should like to refer favourably to the Dorade ventilator. Despite its appearance and the many efforts to design something better, it still leads the way in supplying maximum air and minimum water.

Like other vents, the Dorade can admit solid water if fully immersed in a capsize. Preparation for the most extreme conditions should include replacement of the cowl with a deck plate. Similar positive closure for vents of any kind should always be available. In this vein it is well to avoid companion-ways and other deck openings that are away from the centreline where they are better protected from down-flooding.

Touching briefly on other aspects of safety and comfort we should consider strong, well-located hand rails and we should be sure that sharp corners are eliminated by generous rounding. Galleys should be arranged so that cooks can wedge or strap themselves in place and, if possible, out of the path of spilled hot food. The water supply must be divided between several tanks, each with its individual shut-off valve. This will save the supply in the event of leakage, and also provides control of weight distribution and reduces the large free surface effect of water surging about within the tank Engine exhaust systems may admit water in bad weather, though careful design can minimize that problem.

Rigs must be designed for the high but uncertain loads of heavy weather. It seems evident that many racing rigs lack the strength to stay in place. Improved analytical methods such as finite eleme design have not replaced basic calculations based on the righting moment and the consequent rigging loads that apply tension at the chain plates and compression in the mast. Most designers use Euler column methods, often with assumptions on end fixity and safety factors based on their experience. According to such assumptions the safety factors will vary, but they must be generous so as to be ready for the unexpectedly severe conditions of heavy weather sailing.

Rig geometry and sail shape seem to be a matter of personal preference. Under severe conditions, however, the presence of two independently supported masts can be recommended. Strong storm sail and the rigging to set them quickly and easily are essential to a well-found offshore yacht. The storm sails should not be too large. No more than one-third of mainsail area is suggested for the storm trysail and about 5 per cent of forestay length squared for the storm jib. Sail area relative to stability can well be considered in the light of the home port and cruising grounds, and primarily as it relates t comfort more than to safety. Sail can always be shortened, but too large a working rig means frequen reefing or sailing at an uncomfortable angle of heel.

The areas of storm sails given above are very close to those defined in the International Sailing Federation (ISAF) Offshore Special Regulations. Although drawn up for racing yachts there is a grea deal of good material in these regulations. I recommend a review of this booklet to anyone preparing to sail offshore.

On the subject of hull geometry I have stressed the ratio of beam-to-hull depth. There are other considerations, less important but still meaningful. Positive and easy steering control is one such. In this day of analytical yacht design there is still no subject more deserving of intensive study than tha of balance and steering control. Possibly the lack of understanding explains why there are few subjec that stir greater differences of opinion than the shape of the lateral plane, including keel and rudder. Let me outline some of the problems and some partial answers.

A typical broach by a modern racing yacht, in this case a Mumm 36. If the balance between spinnaker and mainsail is lost, the boat will heel over and forces may be generated that are more than the rudder can correct. The yacht will adopt the angle shown, and due to the buoyancy of the wide stern the rudder may be partly out of the water, making recovery difficult. Although this is a frequent occurrence with modern racing yachts, and unnerving for those who are not accustomed t it, damage to the yacht or injury to the crew is rare. *Photo: PPL*

Course stability is often characterized as that condition in which, without the adjustment of the steering mechanism, a boat sailing a given course when diverted by an external force will return to th initial course. This could be a definition of self-steering ability. Many boats can be trimmed to steer themselves under the right conditions, but few will do so on all courses and wind strengths. The force involved and the direction of their application and the tendency of the hull to turn one way or another at different heel angles and speeds form a very complex system, and one that is difficult to balance. We can accept these difficulties and yet ask for steering that is light and responsive. Even that can be hard for the designer to assure, but I believe that there are a few helpful steps.

A long keel is frequently cited as the best solution. Probably it is, if light weather speed is less important than good manners on the helm, and if the length extends well aft. The disadvantage is the great wetted area that goes with the long keel. Such a keel seems to do two things: turning is necessarily less abrupt and, second, a large part of the lateral plane is abaft the centre of gravity. Think of this the other way around, keel area forward, and visualize a sea turning the boat. It is as though the boat were being towed from a point abaft the pivot point so that the further the new course departs from the original, the further the inertial direction departs from the course, thus causing the boat to turn continually further from the intended direction. Conversely, if the tow point, the CG (centre of gravity), where the force is applied, is forward of the pivot, the CLR (centre of lateral resistance), then the more the course changes the more the direction of the inertial, or tow, force is directed back towards the original course. I should add that this principle of sailing balance is not universally accepted, though to some it seems evident. This principle was first brought to my attentio by Dr John Letcher.

Small wetted area carries with it advantages that have resulted in the almost universal adoption o the short keel and separate rudder. Comparatively it means equal performance with less sail area, especially in light weather, or to windward when speeds are low. Using a short keel the required position of the ballast dictates the location of the keel that further dictates the location of the CLR. This disadvantage can be lessened by locating disposable weights as far forward as possible, permitting the ballast keel to come aft, but such gains are limited and the best available strategy to move the CLR aft seems to be to use a large skeg and rudder. These serve the function of feathers on an arrow. Most new boats follow this pattern and, if the ends are balanced, they can behave well, exhibiting no loss of steering control, ability to heave-to or other good seagoing characteristics.

Other characteristics that seem to contribute to good manners are reasonably balanced yet buoyar ends, and moderate to light displacement. Both minimize trim change with increasing heel so that th unavoidable changes in the yacht’s tendency to alter course occur gradually and the abrupt applicatio of helm is seldom needed. Easy and positive control is valuable in a big sea.

For the sake of an easy and steady helm the pressure of the water on the hull must be evenly distributed and constant over the range of speed and heel. Long lines, minimally rounded, with relatively constant curvature, make for constant water velocity, and thus constant pressure, over the hull surface. Any short quick curve in the path of the water implies a quick change in pressure on the hull surface and, very likely, a quick change on the helm. Again, a light displacement hull with moderate beam and rather straight lines in the ends best meets these conditions.

The motion of a yacht in rough water is probably better understood than is balance under sail. It depends a great deal on the weight and the way it is distributed. Weight distribution may be considered in any desired plane, usually in longitudinal and transverse senses. It is measured by the moment of inertia and is usually expressed as the gyradius which relates the moment of inertia to displacement. The former is the sum of the products of all weight elements and the squares of their distances from a chosen axis. The radius of gyration, or gyradius, is the square root of the quantity, moment of inertia divided by the total mass. It serves as a measure of the yacht’s resistance to acceleration around the chosen axis. Thus a large gyradius, either longitudinal or transverse, tends towards easy motion and is desirable in terms of comfort. In passing it might be observed that the need for a very minimum longitudinal gyradius has become an article of faith among racing sailors. One suspects that they are right more often than not, though studies of resistance in waves show mainly that the weight distribution that results in synchronism with wave encounter is clearly bad; otherwise the effect is small.

Weight itself, or – more correctly – mass, also slows acceleration so that the motion of a heavily built boat tends to be comfortable. Being heavily built, elements of mass such as framing and plankir increase the moment of inertia. In this calculation the rig, due to its distance from the centre, makes a major contribution. Anyone who has experienced the loss of a mast in rough water will confirm the quickened motion that followed. Thus, by resisting sudden roll, a heavy rig contributes to both comfort and safety, as studies have shown that, by increasing the transverse gyradius, resistance to capsize in a breaking sea, like that of the 1979 Fastnet Race, is greatly enhanced.

Variations in hull shape are most significant as they relate to displacement and stability, but som other effects of shape are worth noting. I have referred above to balance between the ends. This does not mean anything like true symmetry. My approach was by eye, which spells guesswork, possibly judgement, though today it is easy to check heeled static trim with a computer, a step towards eliminating excessive trim change.

It is well to avoid flat areas in the hull. These can easily develop in the ends, especially in a light displacement design where the fore-and-aft lines become pretty straight. If sections have a moderate U ~~shape, rather than a V, the flat area that occurs where straight lines cross in a surface will be~~ avoided. Even some slight rounding on a long radius extends the period of impact, reducing the tendency to slam.

Freeboard is another characteristic on which moderation is a good guide. High sides increase stability range but present a large area exposed to the impact of a breaking sea, while a high point of impact increases the overturning moment. Low freeboard leads to the early flooding of the lee deck with its sheet leads and fittings. Related to freeboard is sheer. It can be argued that this has more to d with appearance than seaworthiness, but I think a good sea boat should keep her ends above water without excessive freeboard amidships. Let us agree that the beauty of the Watson and Fyfe boats of the early part of the century was also functional.

Cockpits that can hold a great deal of water can be dangerous, but may be considered in relation t the size and reserve buoyancy of the hull. It is essential that all cockpits will be self-draining through scuppers, which should be large. Deep cockpits offer protection and comfort, but their effect on buoyancy must always be considered. One’s priorities may play a part in cockpit dimensions, but the smaller cockpit must be the safest in the end.

The conditions we are considering are less than ideal for centreboarders. They have their supporters and I have been responsible for many centreboard designs. I always tried to advise the owners that capsize was possible (although I hoped very unlikely), but in many cases the stability range was less than I should have liked. In other cases where draft was not too restricted so that the ratio of beam to depth was not too great, and other details such as freeboard and deck structures were appropriate, the stability range seemed fully acceptable. Among S&S-designed centre-boarders, *Sunstone*, previously named *Deb*, seems a good example of a centre-boarder suited to heavy weather sailing (Fig 1.3) due to her rather deep hull.

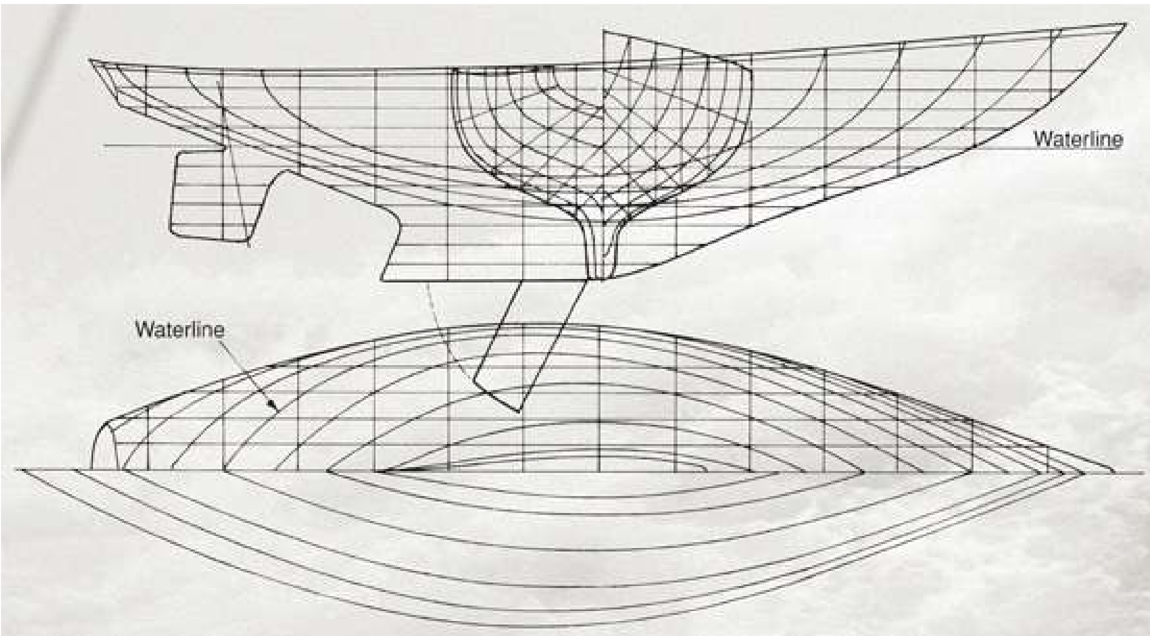


Figure 1.3 ABOVE The lines plan of *Sunstone*, previously named *Deb*. Her present owners, Tom and Vicki Jackson, live aboard throughout the year and have achieved outstanding success in RORC races

I hope it has been useful to consider, one by one, a number of specific characteristics. While each has an influence on the ultimate ability of a yacht, it is always the combination that counts. No individual dimension means too much on its own. Good performance can be reached by different path and, finally, the good combinations are the ones that work (Fig 1.4).

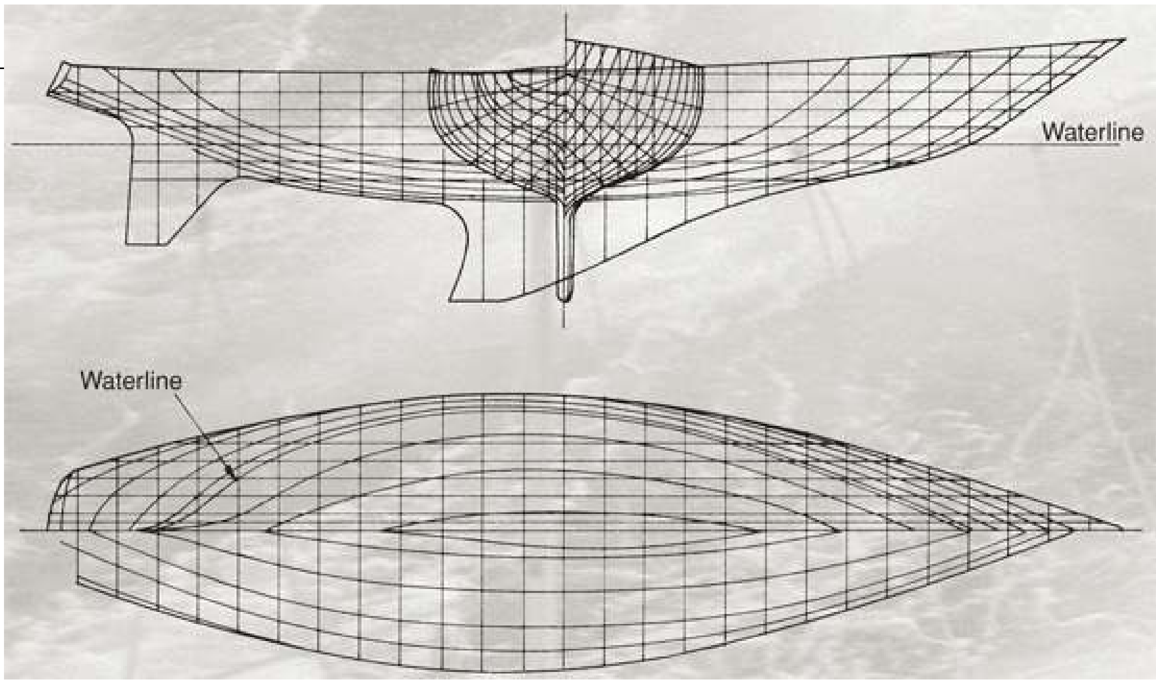


Figure 1.4 The lines plan of *War Baby*, previously named *Tenacious*, winner of the 1979 Fastnet Rac
Her present owner, Warren Brown, has cruised extensively in her.

When I think of the boat in which I should be happiest in meeting heavy weather I visualize one that is moderate in every way, but as strong as possible. I should avoid extremes of beam to depth or depth to beam, either very light or very heavy displacement, or a very high rig. I should like the ends to be buoyant, but neither very sharp nor full, and neither long nor chopped right off. Though I have stressed resistance to capsize, in my own seagoing experience I have never been worried on that scor but I have occasionally been concerned about leaks or the strength of the hull or rig. In the final analysis, I recommend moderate proportions and lots of strength.

Comment

At one time yachts were built with colossal strength in reserve, but nowadays, with better knowledg of stress and materials, and the ever-present quest for better performance, yachts are designed with much lighter construction. Olin Stephens' emphasis on the necessity for structural strength is a reminder of current instances when an overly light construction caused disaster.

In 2001 two British lives were lost when an Australian Farr 38 called *Rising Farrster* capsized o the New South Wales coast when her keel broke from the hull. The coroner, John Abernathy, said that 'the primary cause was inadequate hull thickness around the keel washer plates', ie the hull wa simply not strong enough to support the twisting force of the keel when the yacht heeled over. It emerged that the hull was built to the minimum standard required by Australian law, but not to the thickness stipulated by the designer, Bruce Farr. Subsequently the chairman of the Cruising Yacht Club of Australia's sailing committee advised participants in the Sydney Hobart Race to 'check the bilge and satisfy themselves that the designed thickness of hull was actually there'. This can usuall be achieved quite simply, as will be seen later.

This sad occurrence is not an isolated case, and may be more common than is supposed. Indeed another similar accident occurred in April 2005 when a crewmember died when the keel of his 12.8 (42ft) yacht came off. The building company put out various statements. One of these assumed that the yacht had hit a rock, which was denied by the crews, past and present. The survey report on the damaged yacht stated that 'the bottom section of the yacht as found did not have sufficient strength in the areas designed to take up the forces generated by the keel due to serious manufacturing defec in the laminates and bonding. The wall thickness was between 12mm and 17mm rather than the 25mm or more that was thought appropriate.'

Yacht designers sometimes mention that boat builders do not build a boat exactly to the specification that was designed. Some yacht builders not only adopt their own ideas but simply skimp on the number of laminates used in laying up a hull, thereby saving considerable cost in labo and material. The inexperienced racing owner is likely to be pleased to find his boat is 'down to weight' or even lighter than expected, as to have a light boat is part of a racer's mantra.

There must come a point when lack of structural stiffness leads to loss of boat speed in addition to the danger of losing the keel, or other structural failure. Keeping weight out of the ends of a yach is also included in the racer's mantra, but the ends of a yacht are the most vulnerable to knocks, suc as berthing incidents and, with some modern yachts, the ends are not even built to withstand the minor collisions of normal use, let alone a nudge from a whale. As Olin Stephens simply says, 'a yacht should be built as strong as possible'.

In the case of light displacement yachts, there is little margin of safety in hull design. Thus the designer's laminate specification should be most strictly adhered to. In 2000 a yacht builder in Britain supplied a 10.6m (35ft) 'one-design' racing yacht in which the hull thickness adjacent to the keel was 30–40 per cent less than some other yachts in the class. In this case two different builders had built the class, but the keels and keel bolts were made by the same keel manufacturer who said that all the keels and keel bolts were virtually identical. The second manufacturer produced yachts which were up to 500kg lighter than the first, and it was evident from the exposed height of the keel bolts that there was less hull thickness at the keel intersection, compared to those of the first manufacturer. The matter came to light when external cracking appeared over the length and width the keel flange, which defied straightforward remedy. It was apparent that the hull, which was bending significantly under load, did not properly support the keel. Such movement was borne out i practical trials, as the saloon table supports happened to be attached to the keel bolts, and thus reflected the keel's lateral movement whenever the yacht tacked.

To assess the depth of the hull at the keel it is necessary only to drill a small diameter hole through to the keel or the keel flange, and measure the depth. Of course the hole needs to be properl filled afterwards, but there is no surer way of knowing the true hull thickness at this vital point. The designer, or the designer's drawings, should give the designed depth of hull adjacent to the keel, and a rough guide is that the hull thickness should be no less than the diameter of the keel bolts.

In the last case mentioned, the floors were reinforced with unidirectional glass fibre, and substantial areas of the keel area were stiffened with up to eight layers of laminate, where access allowed, and no further cracking occurred subsequently. As a matter of interest to racing yacht owners, the scantily built yachts produced by the second yacht builder were never as fast as those built by the first builder, suggesting that, in this case, gain in hull speed through reduction of weigh might have been more than offset by the loss of structural stiffness.

Another increasingly common failing is when the keel itself breaks in two, usually near the root In this case it is almost invariably fabricated steel and composite keels that are to blame. These are sometimes simply not designed and manufactured to cope with the forces involved. An example is when welding has taken place without full penetration of the joint, though any welded structure generally has poor resistance to fatigue.

The EU construction regulations do not apply to racing yachts used exclusively for racing thoug in practice, production racing yachts are required to have a RCD certificate. Prospective owners of yachts that do not require an RCD certificate will be wise to make themselves aware of any instance where their vessels do not comply.

I am grateful to Ian MC Campbell, Principal Research Engineer of the Wolfson Marine Unit MTIA, School of Engineering Sciences, University of Southampton, UK for the following information:

In the past, designers used the ABS Guide for Building and Classing Offshore Racing Yachts, ar its use was stipulated in Safety Regulations and some Class Rules such as the Volvo Ocean 60s. It was, however, effectively withdrawn by the ABS as were other Classification Society Rules when th Council of European Communities Recreational Craft Directive 94/25/EC, commonly known as the RCD, came into force for vessels up to 24 metres in length. Associated with the RCD is the new harmonized ISO/CEN Standard 12215–5 ‘Small craft – Hull construction/scantlings – Part 5: Desig pressures, design stresses, scantling determination’ but unfortunately this had an extremely long gestation.

The ABS Guide contained clauses concerning keel attachments and included grounding loads so provided a good basis for building robust structures. Indeed there were reports of Volvo 60 yachts grounding at speed and sustaining little serious damage.

The new ISO 12215 standard is due to be published in 9 parts, and whilst the current part 5 contains less about structural details than the former ABS Guide, part 6, which is in draft, and part 9 will be relevant to keel construction and attachment.

There are exclusions to compliance with the RCD, including yachts intended solely for racing, however most European yachts will comply with the RCD and the associated standards.

2

The stability of yachts in large breaking waves

ANDREW CLAUGHTON

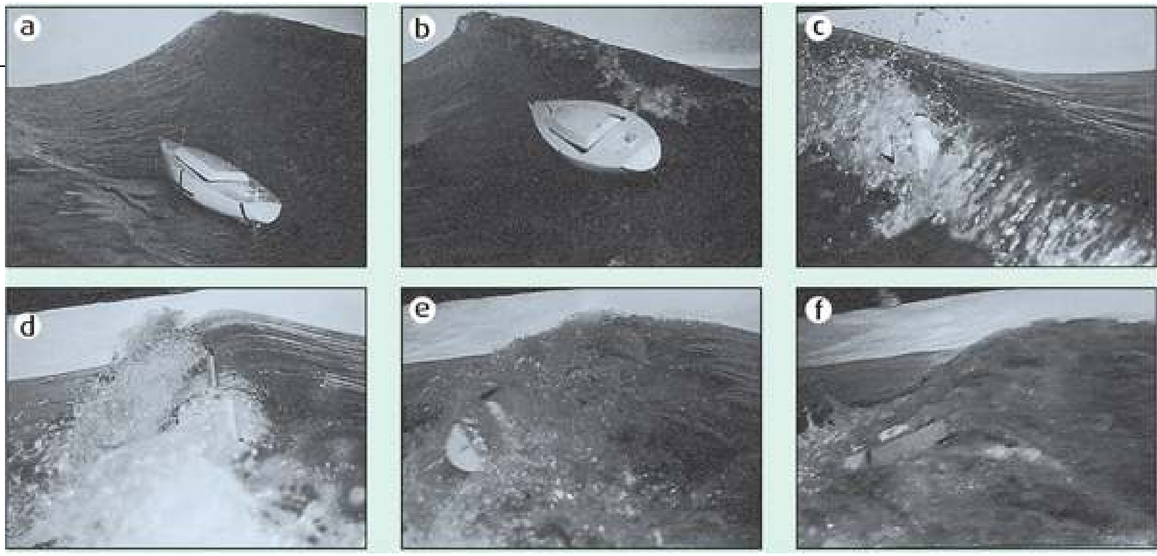
Causes of capsize

WHAT CAUSES A YACHT TO CAPSIZE? Sailing dinghies and lightly ballasted day-sailers such as J24 can be laid flat and capsized solely by the pressure of wind in the sails. In larger yachts the neare equivalent of this is the broach whilst under spinnaker. In a bad broach the mast can be pressed down as far as the water, but once the heeling influence of the spinnaker is removed, the yacht recovers to a upright position. Experience shows us that, in flat water, gusts alone cannot capsize a yacht. Even when encountering high and steep waves, the story remains the same. The action of wave slope in heeling a dinghy or daysailer may assist the wind in producing a capsize, but a conventional yacht’s stability is such that it cannot be capsized by even the combined action of wind and waves, no matter how high or steep.

It is *breaking waves* that cause capsize; if the yacht is caught beam-on to breaking waves of sufficient size, then the exaggerated steepness of the breaking wave front, coupled with the impact of the jet-like torrent of the breaking crest, will knock the yacht down to a point where the mast is well immersed. At this point the yacht’s fate is decided by its stability characteristics; it will either return to an upright position or carry on to an inverted position, where the boat may remain for some time until another wave disturbs it sufficiently to flip itself upright. If the wave is high enough or the encounter with it is timed appropriately, then a full 360° roll will be executed.

How big do breaking waves need to be to cause this type of behaviour? Unfortunately, the answer is ‘not very big’. During the model tests that were carried out to investigate the problem, when the breaking wave was 30 per cent of the hull length high, from trough to crest, it could capsize some of the yachts, while waves to a height of 60 per cent of the hull length would comfortably overwhelm al of the boats we tested. In real terms this means that for a 10m (33ft) boat, caught in the wrong place, when the *breaking* wave is 3m (10ft) high, this presents a capsize risk; and when the *breaking* wave i 6m (20ft) high, this appears to be a capsize certainty in any shape of boat. The word *breaking* is in italic to stress that it is breaking waves that present the danger, while big waves in themselves are no a problem.

As shown in the photo overleaf, the model tests were done in waves that broke all along their cres at the same time, unlike the waves at sea where short lengths of crest break as the wave systems interact. Once the breaking crest at the point of impact is as wide as the boat is long, then its full effect will be felt.



A fin keel parent model under test showing beam-on 360°capsize.
a Beam-on to a large wave.
b Crest begins to break.
c 90° heel angle (transom visible).
d Upside down (keel and rudder pointing to the sky).
e Nearly upright again.
f Returned to normal!

How can capsize be avoided?

The simple answer to avoid capsizing is to avoid breaking waves. This does not necessarily mean staying tied to a mooring, but rather in avoiding certain sea areas in wind or tide conditions where breaking seas may be thrown up. For example, to help their small-boat fishermen avoid breaking waves, the Norwegian authorities define certain no-go areas as part of their weather forecasts.

Taken a step further, even if caught out in extreme conditions of wind and wave, a technique of avoiding the breakers can be employed, but on a more local scale. During the 1979 Fastnet Race man yachts were able to keep sailing, and actively pick their way through the waves, avoiding the breakin part of the seas, much as a surfer keeps to the unbroken part of the wave by tracking across its face. Once the boat is to one side of the breaking part of the crest the danger is over, and even delaying the moment of impact until the breaking wave has dissipated some of its energy will reduce the capsize risk. The wave is at its most destructive at the point of breaking and immediately afterwards. Active sailing also keeps the boat from being caught beam-on to the seas, which is its most vulnerable position. The risk is that a mistake in steering might cause a broach which results in the boat being le beam-on to the waves. This technique does, however, need a strong and competent crew to execute it for long periods of time. It is nevertheless a well-established and successful technique for dealing wi heavy weather.

As was demonstrated by crews' experiences during the 1979 Fastnet, it is not always possible to avoid capsize situations. Due to crew fatigue, or plain bad luck, a yacht, especially if shorthanded, may encounter a capsize or knockdown incident. The research carried out in the wake of the 1979 Fastnet Race has been aimed at evaluating what features of hull design contribute to a safer yacht in survival conditions.

So far I have written in general terms about stability, but we cannot go much further without sample content of Adlard Coles' Heavy Weather Sailing, Sixth Edition