Hull and Deck Integrity

Pacific Offshore Academy

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Abbreviations

ISAF The International Sailing Federation
http://www.sailing.org/
This is the source of the RRS, OSR, ERS, and many class rules.
An extremely valuable resource.

US Sailing
http://home.ussailing.org/
U.S. Versions of the RRS and OSR add to and modify the ISAF original

OSR "ISAF Offshore Special Regulations Governing Offshore Racing for Monohulls & Multihulls"
Available through ISAF & US Sailing (includes US Sailing Prescriptions)
OSR references in this article relate to the 2010-2011 edition

RRS Racing Rules of Sailing
Available through ISAF & US Sailing (includes US Sailing Prescriptions)

ISO International Organization for Standardization
http://www.iso.org/iso/home.html
Source of the current standards for yacht structure and stability

ANSI American National Standards Institute
http://www.ansi.org/
Another source for the ISO standards.

DNV Det Norske Veritas
Norway based shipping standards organization.

ABS American Bureau of Shipping
U.S. based shipping standards organization.

Lloyd's Lloyd's Register of Shipping
Great Britain based shipping standards organization.

ORR Offshore Racing Rule
http://www.offshorerace.org/
ORR developed from Americap, which developed from IMS (International Measurement System), which developed from MHS (Measurement Handicap System). All of them are based on performance prediction from the same VPP (Velocity Prediction Program), which has gradually evolved since the mid seventies.

AVS Angle of Vanishing Stability. The heel angle where the righting arm goes to zero, typically in the 105 to 135 degree range. If the boat heels to a lower angle you can expect it to self-right. If a greater angle, it will turn turtle.

LPS Limit of Positive Stability. The same as AVS. LPS is the ORR term.

SI Stability Index. ORR modifies LPS based on length of boat and beam to length ratio to derive SI. The length and beam modifying factors were empirically developed following the 1979 Fastnet Race disaster.

SST A “Self Survey Tip” in this article

Definitions for some of the less well known terms used

scantlings: The dimensions of structural elements used in shipbuilding, the collective dimensions of the various parts, particularly the framing and structural supports.

sea cock: A valve in the hull that protects the plumbing pipes from water from outside the vessel.

downflooding point: An opening that allows the entry of seawater into the hull or superstructure of an undamaged vessel due to heel, trim, or submergence of the vessel. An opening capable of flooding the hull that can't be made watertight, or might be left open by the crew.

hawse hole: An opening in the hull, through which anchor chains or mooring lines (“hawsers”) are run. Note hawse holes are not usually a downflood point, since they are not usually open to the hull interior.

Overview

Hull and structure is a broad subject. Many of the points touched upon in this article deserve a class of their own, and may get one as the subject matter of the Pacific Offshore Academy begins to expand.

The first question you may ask is what type of boat is best suited for an extended offshore voyage? The short answer is – the boat that you own, or can afford. Well, OK. People have crossed oceans in all manner of crazy craft; boats of all sizes and descriptions. Dugout canoes, boats made of leather, logs, or plastic bottles; and those were some of the smarter ones. Many of them even made it to the other side. Perhaps a better question – what qualities should a boat have so that the voyage will be one of enjoyment, rather than a fight for survival? In most cases the answer lies in preparation.

First Premise

Here is a summation of this entire article: *Keep the water outside the boat.* This comment may seem facetious; but it is not. Rather it deserves treatment as a mantra, to be repeated over and over as you prepare your boat for the voyage. *Keep the water out of the boat; keep the water out of the boat.*

A professor of naval architecture once criticized me for referring to a boat as a “vessel”. The professor shall remain nameless. Let's call him 'Randy Paulling'. 'Randy' told me, “a vessel is for holding the water *in*. A boat holds the water *out*.” In my defense, the US Coast Guard calls them vessels consistently; but no matter your semantics, one thing we all can agree on – we want the ocean to stay outside the boat. Think about it. If you accomplish this simple goal, your boat will remain afloat – you are safe; your clothes, bedding, and food will remain dry – you are comfortable. Safe and comfortable equals happy. Mission accomplished. *Keep the water outside the boat.*

The Big Picture

In the big picture view there are three areas of concern to identify a seaworthy hull:

1 Hull Structure. Is the boat strong enough?

2 Stability. Is the boat stable enough? Does it have enough righting moment to recover from a severe knockdown?

3 Attachments and penetrations. Are all the fittings, joints, through hulls and openings properly mounted and sealed?

For the most part, points 1 and 2 above are determined by the designer before you get the boat. Once the boat is built you don't have much control over those aspects. Nevertheless, some information and knowledge will be helpful; so you can at least begin to ask the right questions. Point 3 – attachments and penetrations – that is the meat of this article and the focal point of your boat preparation.

The bible for much of this is the “ISAF Offshore Special Regulations Governing Offshore Racing for Monohulls & Multihulls” (OSR). This is a booklet that has been around for decades and is re-issued every two years. If you are preparing for a Pacific Cup, you will hear too much about this booklet and will grow to hate it. Rule of thumb - If you don't hate it yet, you haven't reviewed it thoroughly enough. Even if you are not doing a race it is an excellent resource for any sailboat. If you are a cruiser, please ignore “regulations” and “racing” in the title. Read the book. In its sometimes clumsy way, it is full of good advice and wisdom.

Two final points that need emphasis here – *maintenance* and *inspection*. A dirty bilge, or a locker that hasn't been emptied in years may hide a developing structural problem. A rudder that hasn't been pulled for inspection recently may have bad bearings or a corroded post. One corroded hose clamp can sink your boat. Keep everything clean, accessible, and in good working order.

Hull structure

Yacht designers and naval architects are conscientious people. As I write this, I personally have been in the yacht design profession for 40 years, and I can't think of a single designer who would not fit that description. We may come from a wide variety of backgrounds and different levels and styles of education; but we all want our boats to survive their intended purpose. We want the sailors to get to the other side of the pond safely. That being said, there is close to zero regulation on yacht structures in the U.S., although that picture is gradually changing. Until very recently, what regulation there was generally applied only to racing boats.

Structural Regulations and Guidelines -A brief history

(You may skip this history section. It will not be on the quiz.)
In the Western world there are three big organizations involved in structural regulations for merchant ships: Lloyd's, DNV, and ABS. (see the Abbreviations section). Each of them has dabbled in the pleasure boat world from time to time. I think they view it as a happy diversion, kind of like a coal miner coming home to

play with his son's Tonka trunk in the sand box. In the seventies, when Carl Schumacher and I were both working for Gary Mull, references on how to engineer a sailboat were limited and scattered. Lloyd's had an early version out of their rules for fiberglass boats, but the early version was close to worthless and essentially assumed everything was built out of chopped strand mat. There were ancient guidelines in the U.S. by Nevins and Herreschoff, basically seat of the pants guidelines for the structure of wooden boats; there were rules for building 12 meters and the like. Gary got the idea of unifying the guidelines that were out there. 'Let's take the various guidelines, input the known material properties, and reverse engineer to find the loads that were implied. Mix in some common sense and logic. Derive a new book based on engineering formulas that would work for any construction material.' It was a brilliant and far-sighted idea; and Gary led the charge to implement it. This effort led to the ABS “Guide for Building and Classing Offshore Racing Yachts”, first published in 1981, an excellent booklet. I have been engineering boats to it ever since. For a few years, race organizations were trying to force plan approval through ABS. It was an expensive and rather annoying process for designers and owners, and it wasn't long before ABS shut the program down and got out of the yacht review process. The guide, however, was still widely used.

Recently, driven by European regulations, ISO has gotten deeply involved in the yacht structure and regulation game. The current edition of the OSR has dropped the ABS guide entirely and now refers only to the new ISO regulations, as discussed below. The good news is that the ISO regulations are also very good and the scantlings derived are generally very similar to those from ABS. The bad news is that plan approval has once again reared its ugly head; and so far is just as expensive and annoying as the ABS system.

Current Structural Requirements

OSR paragraph 3.03 “Hull Construction Standards (Scantlings)” points you to the applicable standards that a designer should use to engineer your boat's structure. In 2010 this paragraph changed so that all monohulls built from 2010 onward doing an ocean race (Category 0, 1, or 2) must be engineered and built to ISO 12215 Category A. (Note: ISO 8666 - also referenced in this section - just defines how critical dimensions referred to are measured. Essentially it defines how things like length, beam, and displacement are to be measured so there is consistency when the terms are used in ISO 12215.)

ISO 12215 is a rather rigorous and technical cookbook that defines the loads and formulas used to engineer a boat. The ISO standards were developed in Europe over the past few years; and boats built in Europe are required to meet the standards. It is conceptually similar to its ABS predecessor. In my experience

scantlings determined using the ISO regulations are nearly identical to those from ABS; but it is slightly more rigorous in some areas.

Evaluating Boat Structure – What Can You Do?

If your boat is new you will want to put it through its paces, sail it hard upwind and down in the biggest waves you can find. Don't make a trans-oceanic voyage your first real test of the structure. San Francisco is a great testing ground. It's not uncommon for a boat to sail a few years in Southern California without issues; and then start breaking things as soon as they sail in San Francisco. They may also discover deck hardware leaks that never revealed themselves before.

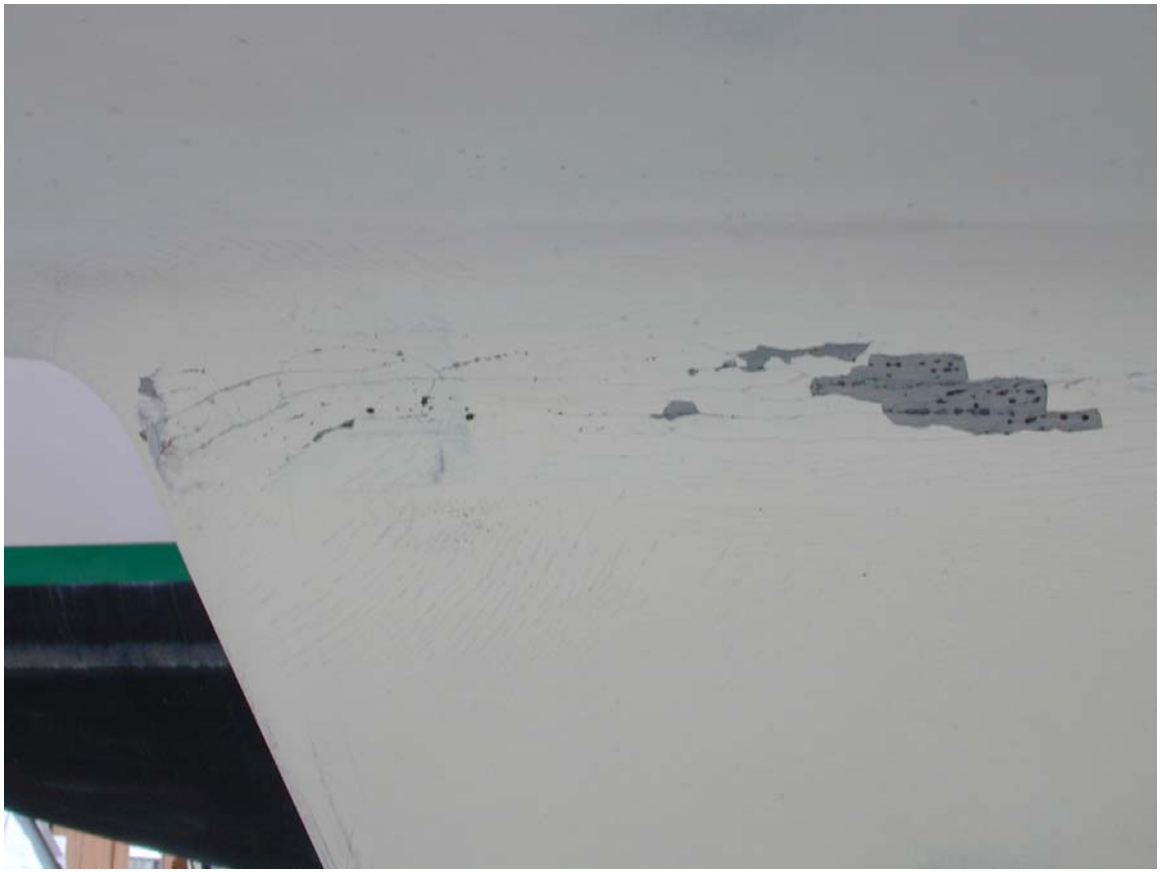
If you have an older boat the teething problems are probably long gone – unless the boat has lived a comfortable life on the farm and never been to the racetrack. Older boat concerns will be decay, fatigue, and damage caused by accidents such as groundings.

Survey It Yourself

Conducting a self survey is a useful exercise for any boat owner. The first place to look for problems are high load areas – chainplates, mast step, keel and rudder attachments, big deck hardware. Also common problem areas are corners – for example: hatch cutouts, or the corners where the house meets the deck. What are you looking for? Corrosion, discoloration, cracks, lifted paint. Fatigue in fiberglass or metals is usually revealed by very fine cracks, often roughly parallel or radiating from a corner. Stress cracks caused by a collision or overload look very much like fatigue cracks. Lifted paint often conceals a structural problem.

Hairline fatigue and stress cracks -microcracks - generally start in the surface layers. Fairing compounds are resin mixed with filler, as is gelcoat. All of these filled resins are more brittle than the structural layers underneath, which typically are resin reinforced with fiberglass, carbon, or aramid. Fillers that are easy to sand are generally the most brittle, while structural fillers like West Systems 404 High-Density are much stronger, less brittle, and much harder to fair. Since gelcoat and fairing layers are always at or near the surface and are more brittle, they crack much more easily than the underlying laminate. For this reason, a boat may show fatigue or stress cracks in the surface for many years without a problem. The good news and the bad news is that the resin layers are fused together. Eventually over time, cracks in the outer brittle layers will start migrating into the structural layers.

Fatigue cracks surrounding a crack through the laminate.
Often found at the corner of a cutout.



Severe fatigue cracking in a keel stub. This keel was close to falling off.

This article will be sprinkled with “Self Survey Tips”. Look for the SST symbol. When in doubt, consult a marine professional:

- marine surveyor
- naval architect
- boat yard

Stability

Stability regulations for monohulls and multihulls are covered by OSR paragraphs 3.04 and 3.05 respectively. In addition, racers sailing under an ORR rating may be required to meet stability standards imposed by that rating rule. OSR 3.04 refers to ISO 12217, a relatively recent and comprehensive standard.

From a safety margin point of view, the key number relating to safety is the AVS, LPS, or SI (see abbreviations). If you are going to sea, you can expect to be knocked down. If a boat is knocked down until the masthead hits the water, that will be a heel angle of more than 90 degrees, about 95 degrees is typical. A boat with an AVS of 100 has little margin left. If you have been measured under ORR, LPS and SI are printed on your rating certificate. Sometimes a sistership has been measured, or was measured in the past under IMS, and that number can be found. You naval architect is likely to have the number. Final option is to test it. This is pretty simple on a small boat, and very informative.

A major concern is whether your boat has any downflooding points (see definitions) that will be submerged when you are knocked down. If you have been laid over to 90 degrees, whether purposefully in the test noted above or accidentally at sea, you may have noted where the waterline is with the boat lying on its side. How close is the companionway to the water? Are there any hatches or opening ports that will be submerged? Do you have any cool below-deck control line openings that will be streaming water into the interior while you are laid on your side? If so, you better know before heading off to sea. Ideally when heeled to its AVS, your boat will have no downflooding points submerged.

Significantly, if your boat was not designed to race under the OSR and not sailing under ORR, you may have no clue what margin of safety you have during a knockdown. Cruisers usually want shallow draft for better access to anchorages. Cruising boats always have more interior and deck gear, more stuff in the rigging – weight placed high in the boat. In contrast, modern race boats often have very deep draft and bulb keels – a low center of gravity. Ironically, racing boats are often much safer than cruising boats when it comes to high heel angle stability. They are certainly more likely to know where the limit is.

Attachments and Penetrations

Let me start by describing the boat building process. Yacht construction is a three step process that goes something like this:

Step 1 Build a strong, watertight, monocoque hull and deck shell.

Step 2 Drill hundreds of holes through the shell.

Step 3 On Friday afternoon, fasten a bunch of stuff in the holes.

Now, even if it is Friday afternoon when you read this and you've had a couple of beers, you may notice that steps 2 and 3 are somewhat at odds with our first premise, “Keep the water out of the boat”.

Let's look at the shell penetrations you are likely to have. We'll examine some key areas of structural concern and methods to prevent leaks, and identify related paragraphs in the OSR where applicable. (Depending on race category and whether you have a monohull or multihull, not all of the OSR references may apply to you.)

Hull Penetrations

Rudder
Keel
Through Hulls
Engine & generator exhaust
Strut drive
Propeller shaft
Cockpit drains
Bowsprit
Kelp Cutters

Deck Penetrations

Mast partners & step
Chainplates
Hull/Deck joint
Companionway
Hatches & Ports
Vents
Tank fills and tank vents
Deck hardware
Control lines openings
Anchor lockers & hawse holes

That's a lot of holes!

The fitting or device will be attached to the hull in a manner fitting one of these categories. These attachment type descriptions are specifically coined for this article. This is not industry slang.

Type PC	Permanently Closed. The original penetration is structurally unified with the hull and or deck; or enclosed in a surrounding structure that is structurally unified, e.g. a tube fiberglassed or welded to the hull and/or deck. Leaks are not possible unless something breaks.
Type F	Fastened, directly attached. The fitting is attached to the shell directly, usually with fasteners, and relies on sealant to keep the water out. Chainplates, deck hardware, through hulls would normally fit this category. If the fasteners hold and the sealant is good it will not leak.
Type HC	Hose Clamped. The fitting relies on hose clamps and hose to hold it in place and keep the water out. The flexibility afforded by a hose mounting is essential for stuffing boxes and most mechanical seals to work properly.
Type MS	Mechanically Sealed. This includes things like stuffing boxes, O-ring seals, and carbon face seals.
Type FS	Flexible Sealed. A bellows or other soft or flexible seal enclosure.
Type O	Open, or not truly watertight. This is a downflooding point.

Rudder (OSR 3.13.6, 4.15.1)

It goes without saying that a rudder is a key component of your boat. Believe me, you will miss it when it's gone. Rudders, steering systems, and emergency steering options are big topics deserving a chapter on their own. The focus of this article is on how rudders are hung, attached to, and supported by the hull. But while we are on the subject, let me just say this – *rudder problems are the most common failures in a race to Hawaii*. Your rudder will experience higher loads in the ocean than in the Bay and will be working continuously for days on end. Big waves and big spinnakers work a rudder hard. An emergency steering system is a poor substitute for your primary rudder. I*f your rudder hasn't been pulled for inspection in the past three years – pull it now*, while you still have time to correct a problem. If there is doubt about anything: evidence of a crack starting, slightly worn bearing, doubt about whether the rudder supports are adequately braced – *fix it*. The sea will have no mercy.

SST You can detect many rudder problems by just horsing the rudder around in a boatyard. Grab the base of the rudder and yank it back and forth as hard as you can. Worn rudder bearings and sometimes structural defects can be detected this way. Rudders develop thousands of pounds of force. You can't break it by hand. Just be careful not to pull your boat off the jack-stands.

Rudders that are hung underneath the hull, as opposed to being mounted on the transom or in a cassette, have two different methods of sealing the rudder post penetration. On many small, tiller steered boats there is a tube enclosing the rudder post. The tube is continuous and watertight from hull to deck. (Type PC seal). This method has obvious advantages in avoiding leaks. There is no opening into the hull. Furthermore that tube is helpful in connecting the hull structurally to the deck – more on that later.

On boats that have wheel steering or an under-deck autopilot, a continuous enclosure tube is not possible because the steering quadrant and autopilot tiller need to be mounted to the post between hull and deck. This system requires a method to seal the top of the hull tube. Various methods include:

- stuffing box (the traditional solution)
- shaft seal http://www.tidesmarine.com/rudder-seal-i.shtml
- watertight bearings
- flexible bellows

A typical rudder post stuffing box

A stuffing box is reliable but I prefer sealed bearings or modern shaft seals as they will likely have less friction. Both stuffing boxes and shaft seals are Type MS seals with a Type HC attachment. The Hose and hose clamp attachment is essential in this case to allow for rudder post deflections. The seal needs to move with the shaft in order to maintain a good seal; therefore the hose attaching it needs to have enough length to allow the required movement.

A bellows style rudder tube seal

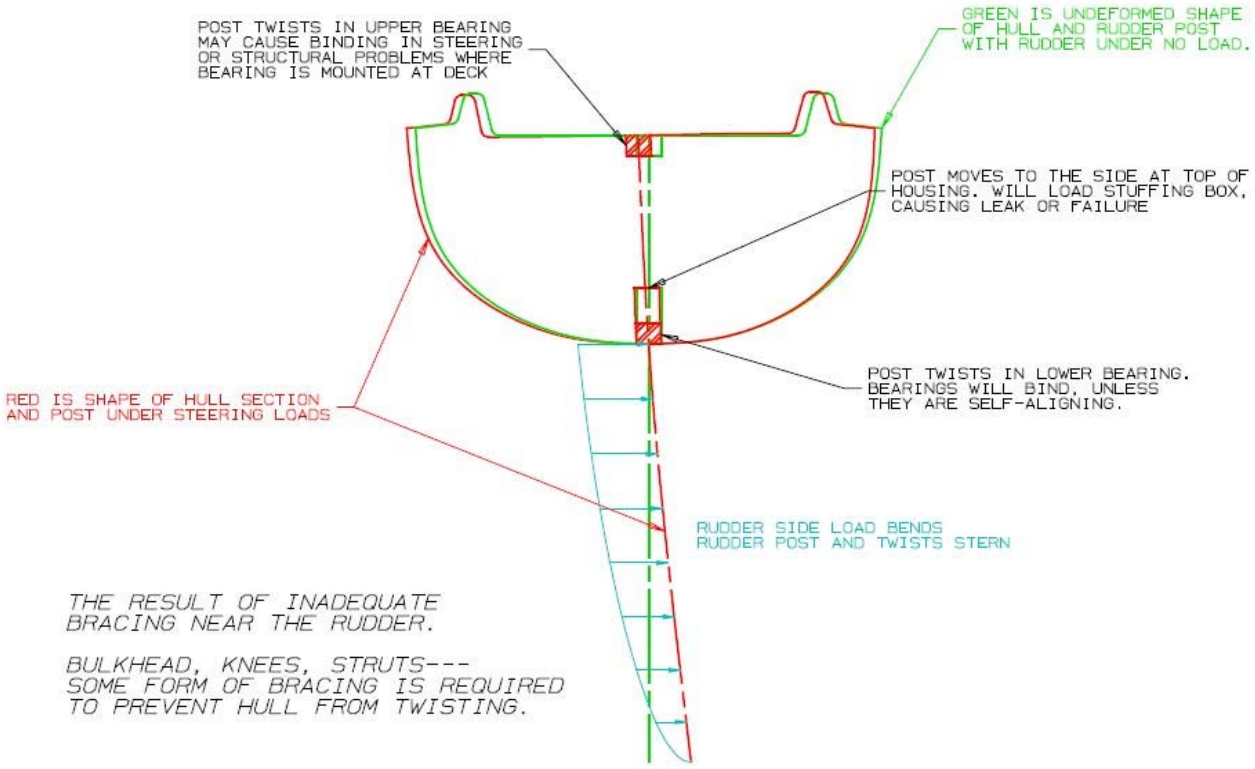
I'm not a big fan of the bellows solution, although if the tube end is well above the waterline and the bellows is a well thought out and robust installation it can work well. Note that the bellows is a Type FS seal with a Type HC attachment. Make sure that with the rudder hard over, the bellows is not stressed.

A post has the same sealing problem to a lesser degree at the upper end if the post passes through the deck or cockpit sole or seat (which it usually does). Typically this deck penetration is not truly sealed. Not much water -rain, spray, deck wash – is likely to get past the upper bearing; but some undoubtedly will. Something to consider and look at on your boat. Will occasional drips here be a problem? What is the likelihood of this penetration being immersed?

Two important potential problems to consider regarding the way the rudder is mounted in your boat:
1 – Is there adequate bracing to the hull and deck near the rudder supports?
2 – What will happen if the rudder post gets wobbly or fails?

Potential problem 1: Inadequate bracing near the rudder is not uncommon. Boats that have sailed for years in the Bay have developed this problem on their first sail to Hawaii. Steering loads twist the stern of the boat, and if there is no bulkhead nearby or other good shear connection between the hull and deck,

deflections can cause a host of problems. When in doubt – add some bracing in this area. A nearby bulkhead is ideal, even a small partial bulkhead connecting the cockpit sole to the hull. Knees where the rudder tube passed trough the hull and deck are helpful. Even diagonal stays from cockpit or deck to hull to prevent distortion can work. The key is to study your particular installation and decide on the most effective path.



Potential problem 2: Let's say your lower bearing falls apart or falls out. The rudder post starts banging back and forth. If you have a stuffing box or a shaft seal, the load that the bearing was supposed to carry transfers to the seal, and the next thing you know the seal has been dislodged and you are taking on water.

Or say the rudder post breaks and you lose the rudder. Stuffing box, seal, bellows – all of them rely on the post being there to close the opening. If the post exits the boat with the rudder, now you've got two big problems – you can't steer and you are sinking. These are problems you should try to anticipate and plan for. Perhaps you tie a wood plug next to the rudder post, big enough to plug the hole if the rudder is gone. Can you have a fabric seal handy that may work?

Skeg hung rudders are not without the potential for problems. Certainly they are at least as likely as spade rudders to have worn bearings or corroded fittings or posts. While the skeg does reduce the load on the rudder post significantly, this just means the post will be smaller, not necessarily less likely to break. If you do have a skeg rudder, check for fatigue cracks in the hull and skeg near the top of the skeg and near the bearings. This is not a common concern but is worth looking for.

Keel (OSR 3.02.3 (relates to canting keels only))

Like most of the hull structure, keel attachments are an area where you have to have faith. Unless there are *indications of a problem* you are probably safe to assume it was properly engineered and built. But before you know if there are indications of a problem, remember the key words: maintenance and inspection. If your bilge is full of dirt, oil, hair, and muck, you can't even answer these questions:

- Are the keel bolts and nuts clean and in good condition?
- Is anything leaking?
- Hairline cracks or detached bond in the keel floors, or in nearby hull or interior molded parts? Problems such as this often show up above the trailing edge of a keel after a grounding, or anywhere in the bilge near the keel if the structure is getting tired or was poorly designed or built.

If you have corroded bolts, mysterious leaks, cracks and/or failed bonds near the keel - consult a professional.

Grounding damage. Note cracks near limber holes and wire runs.
Floor bond to hull failed in some areas.

SST Here is more investigation you can do:

Get your boat out in a good seaway, thrashing to windward, and pull up the floorboards. Look for movement near the keel, put your hands on the structure and feel for it, probe around. Everything moves under load to some degree; if you can feel slight movement it may be OK; but if you can see it, it probably isn't.

SST Another test - if your boat is hanging in a Travelift – grab the keel tip or bulb and yank it as hard as you can, or give it a good kick. If you see anything moving under your miniscule strength, imagine what is happening when that hunk of lead is pounding over a wave.

SST A very common area of concern is the joint where the top of the lead or iron keel mates to the hull. The keel casting is an extremely stiff item in the longitudinal direction, much stiffer than the fiberglass hull and support structure nearby. Since the forward-most keel bolt is inevitably several inches aft of the forward end of the lead, the hull will flex upward and tend to open this joint. A keel with a vertical leading edge will rarely show this problem; but a keel with lots of sweep almost always shows it to some degree, simply because the forward-most bolt is pushed further aft. If the problem is entirely forward of the keel bolts, you are probably OK. If it extends past the forward bolt, you probably have a problem. In any event, you want a flexible sealant in this joint. The more swept the keel is, the more the need for flexibility.

Stress cracks in keel floor caused by grounding.

Through Hulls (OSR 3.10, 4.03)

OSR 3.10 basically requires that any through hull below the waterline having plumbing attached to it must have a “sea cock or valve” permanently installed. Personally, I think the phrase “or valve” should be removed, as it implies that one could have a through hull, bit of plumbing, then a valve and that would be acceptable – no. The whole point is that you don't want you boat to sink because something knocked the hose off the through hull, or a hose clamp came loose. A sea cock is a valve that is directly mounted to the hull (Type F). Type F is definitely preferable to Type HC below the waterline, except where the flexible mount afforded by type HC is necessary.

There is some dispute on what kind of sea cocks are advisable. For USCG inspected “vessels” (sorry Randy), plastic sea cocks are not allowed. USCG reasoning – if you have a fire, you don't want your sea cocks to melt. Pretty hard to argue with that. Here's the argument: Few boats have sunk because fires melted their through hulls; more have sunk because electrolysis has made the through hulls fall apart, or corrosion has prevented sea cocks from closing. My own preference is for plastic sea cocks. I recommend Forespar Marelon; and particularly favor their “FlowTech” sea cocks which have a totally flush surface with the hull when closed. If you have metal sea cocks, make sure they are bronze, in good condition, and your electrical system is properly protected from galvanic corrosion.

Engine & generator exhaust

Almost all marine exhaust systems are “wet exhaust”, which means that the engine coolant water drains through the exhaust system after cooling the engine. You need to be sure this water returns to the sea, rather than leaking into the bilge - or worse – back into the engine. And I know your boat is very fast and always outrunning following seas; but sometimes you will be stopped. Perhaps the mast fell down or a crew went overboard. This would be a bad time for a following sea to blast through your exhaust hose and into the engine. Make sure your exhaust system flows downhill toward the exit and you have good water locks. Those flap covered exhaust fittings are a good idea too.

Make sure all segments of the exhaust system are strongly attached. Can they be knocked loose by a crew crawling through the lazarette, by sail bags or other stowage knocking something loose? Having exhaust fumes pumping into the interior is as serious a problem as water intrusion.

Strut drive

Saildrive seals have proven to be very reliable. Does that make you nervous? Me too. Make sure the seal looks in good condition and the zincs are replaced frequently. Saildrives are notorious for galvanic corrosion. It's not uncommon for a power washer to blast one to pieces during a haul-out. It would be bad to have your saildrive fall to pieces at sea.

Propeller shaft

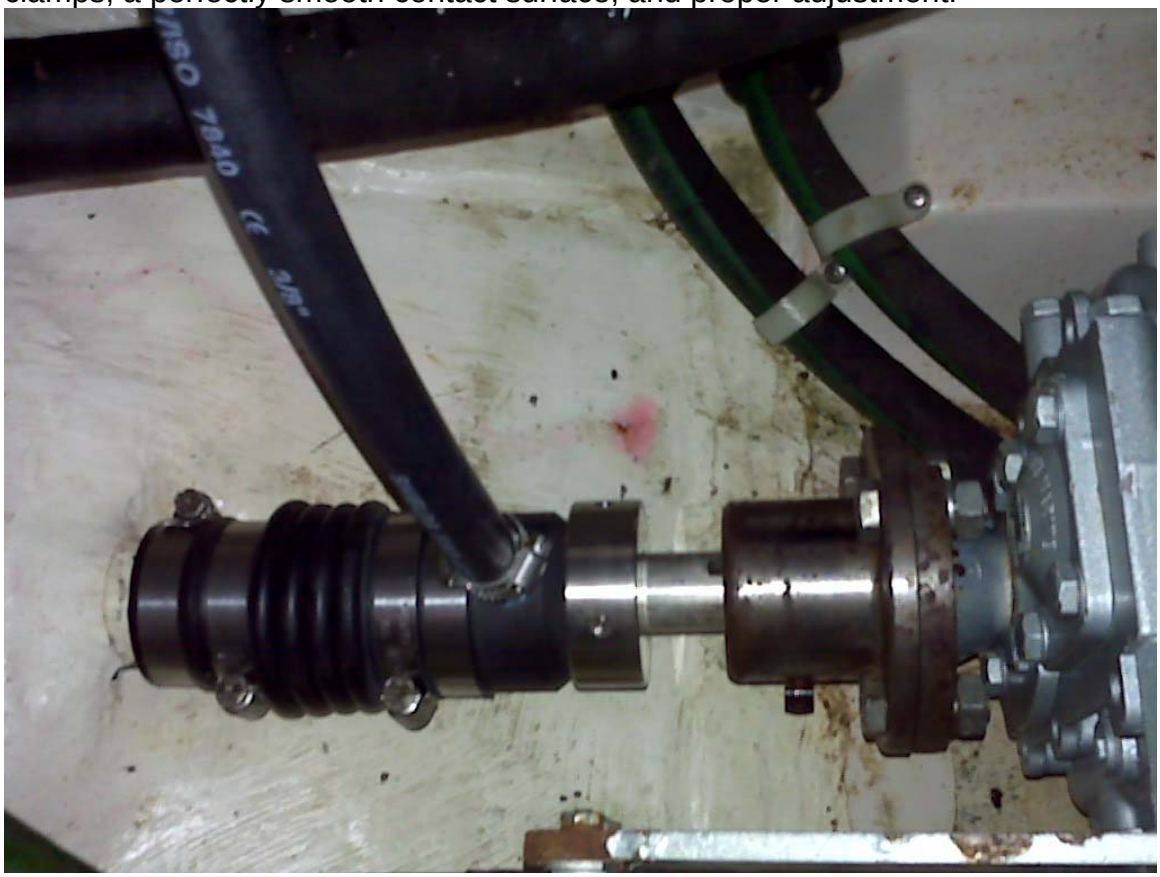
There are two ways to seal a propeller shaft. Both of them are Type MS held in place by Type HC.

First is the traditional and ubiquitous shaft log or stuffing box. These are very reliable; but like every other part you are depending upon to keep the water out,

they deserve inspection and a little care. In our section on through hulls we frowned upon valves that were separated from the hull and attached by hose and hose clamps. Guess what? That's how the stuffing box is attached. Make sure the hose and clamps are in good shape. Double hose clamp if space allows. Occasional drips are typical for stuffing boxes; but if you are having trouble getting a good seal it may be time to replace the packing.

Typical stuffing box. This one needs a little love.

Second seal type is a “dripless shaft seal”, the most common brand being a PSS, which stands for “packless sealing system”. “Dripless” and “packless” are appealing words, and in fact these seals work very well. They do rely on hose clamps, a perfectly smooth contact surface, and proper adjustment.



A PSS shaft seal

Type HC (hose clamp and hose) attachment is essential to both stuffing box & dripless seals to allow for movement between the propeller shaft and the hull. The engine vibrates on its mounts, the propeller shaft flexes slightly. You need an adequate length of hose to allow for this movement.

While some movement is expected you need to minimize it by keeping your drive system in good condition. This means a well balanced propeller, a strongly attached strut, and cutlass bearings that are in good condition. There is nothing like propeller shaft wobble to destroy a good shaft seal.

Final warning – and this is a big one. Like rudder post seals, propeller shaft seals only work when the shaft is there. It is not uncommon for a boat to sink because the shaft coupling was loose. The engine is thrown in reverse and the propeller and shaft propel themselves to the bottom of the sea. Now there is a perfectly

good seal with a big hole in the center. This would be another excellent place to keep a wood plug or two in place, one matching the shaft diameter, perhaps one matching the seal diameter.

Cockpit drains (OSR 3.09.3, 3.09.8)

There are many arrangements for cockpit drains. My own preference is for an open transom. When your cockpit fills with water you want the water to leave in a hurry. Moreover, you want it to depart into the sea, not into the boat; so any opening into the boat that is below the edge of the cockpit is undesirable at best. More on this in the companionway section.

OSR 3.09.08 basically states that your cockpit drains must have at least the area of two 1 inch inside diameter if you are a very old boat or are under 28 feet, or of four ¾ inch inside diameter for everyone else. They must be joking, the pranksters. This may be the only instance where the OSR may be too lax. I would say that your drain is not too big until you are worried about a baby falling through the hole.

If your cockpit drains through a hose or pipe to the transom or hull, the best arrangement for a fiberglass boat is to have a permanent fiberglass tube, strongly glassed in at both ends (Type PC). While this is preferable to a hose, it may not be a good idea to retrofit your cockpit drains with a fixed tube. Often there is significant movement between the cockpit and the hull while sailing. A hose will tolerate this movement; a fixed pipe may not.

If the cockpit drains through a hose (Type HC), same warnings as elsewhere:

- hose in good condition
- double hose clamp
- make sure loose gear or crew groping in the dark will not knock it loose.

Bowsprit

If you have a new boat - or an old boat - you may have a bowsprit. Designers of old boats were not foolish enough to retract the bowsprit through an open hole in the bow (Type FS). If your boat has a bowsprit that retracts into the interior, it should retract into a watertight casing or trunk that drains overboard. If your sprit retracts into the hull with no casing and depends on a flexible seal at the bow to keep the water out, give some thought to how quickly you will sink if that seal blows out as you are surfing down waves, or worse yet, if the sprit breaks off. I would make sure you have a rapidly deployable back up seal and effective plan that everyone on board is familiar with.

Kelp Cutters

Kelp cutters have become fairly common on modern racing boats with near vertical keels. From a leak prevention point of view, there is no worse location to cut a hole in your boat than in the leading edge of a vertical keel on a high speed boat. The water pressure in a kelp cutter tube is enough to create a water spout several feet above the cabin top. If that tube is open to the interior of a keel trunk, water pressure will increase the possibility of leaks around keel bolts. In any event you need a strong, well sealed, and well attached enclosure tube between the keel and the cabin top. This tube is often central to the central living space below decks and will make a fine hand hold for crew moving through the cabin. If the crew can grab it, they will; and it had better be strong enough to serve as a serious grab rail.

Mast partners & step (OSR 3.12)

Mast bases are a notorious source of leaks. If you have a keel stepped mast, then by definition you have a rather large hole through your deck. That hole is difficult to seal properly, and even if it is sealed perfectly, rain and spray will get into the mast interior through halyard exits and leak into the boat at the mast step.

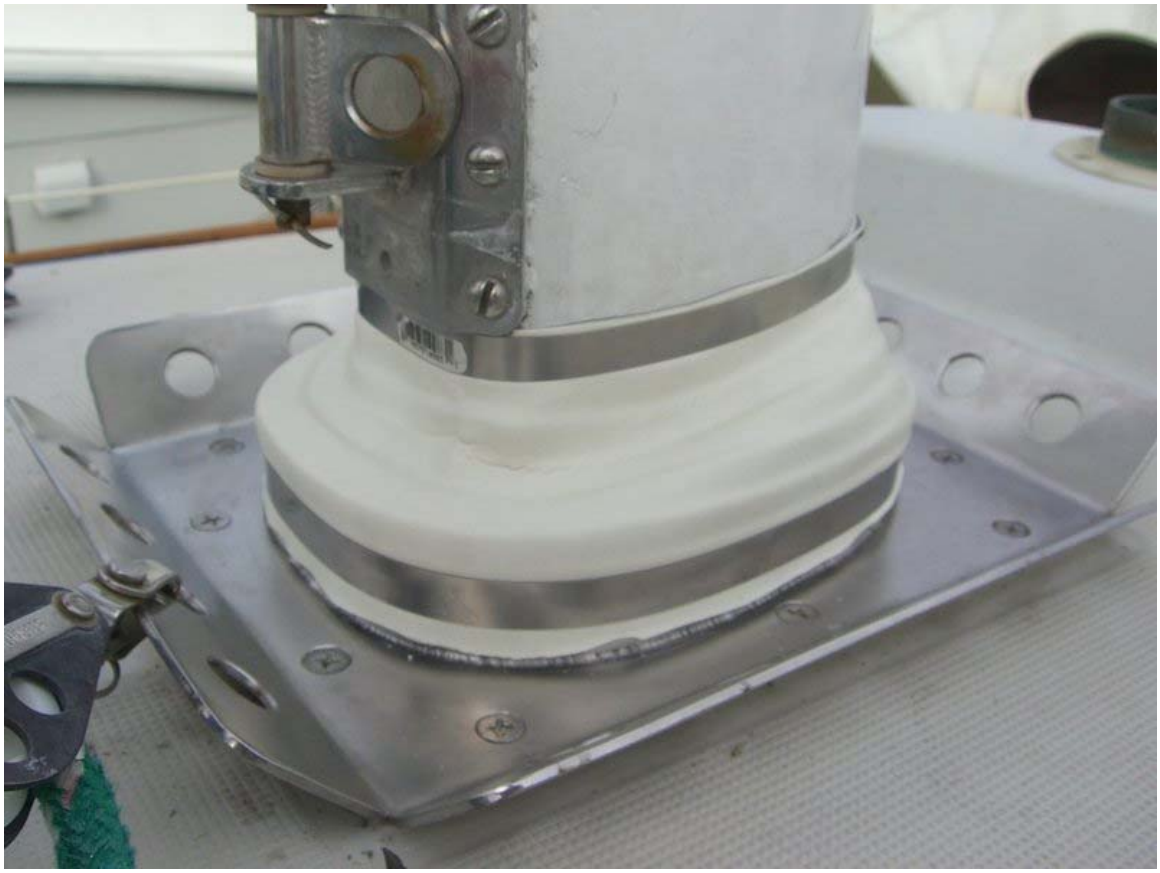
A belt and suspenders approach is the best way to avoid leaks at the partners. A mast should be well braced where it passes through the deck. Spartite has become a common and excellent way to accomplish that. Because Spartite fills the entire void and has decent bonding properties, it not only does an excellent job of supporting the mast, but also can form an effective seal. That is, it forms an effective seal until the mast moves. It is flexible enough to tolerate typical mast movement during normal sailing; but will not stand a significant change in mast rake, or a mast that has been un-stepped and re-stepped.

A mast boot is the “traditional” form of seal and if applied above Spartite or similar seal, then you have double protection. If your mast extrusion incorporates a luff groove, you will need to fill that groove where the mast boot fastens.

Deck stepped masts are relatively easy to seal, since only the wire run and mast step fasteners are potential leak locations.

The OSR paragraph referenced above requires you to securely fasten the heel of the mast to the adjoining structure if you have a keel stepped mast. The reasoning here is if you have a mast step failure or if the mast somehow slips or jumps off the step it can easily punch a hole through the bottom of the hull and sink the boat.

Most of the round the world open class race boats have deck stepped masts. If a deck stepped mast falls down, it usually just falls over with minimal damage to the deck near the step. If a keel stepped mast falls over it can rip a big hole in the deck, an obvious safety concern. On the other hand, a keel stepped mast has structural advantages. The mast itself is stronger (better supported at the base). Furthermore, mast compression loads need to get down to the keel eventually. Extending the mast section to the keel is just more efficient than adding a compression post under a deck stepped mast.



Typical mast boot

If your mast is deck stepped and supported by a mast column, the loads are the same at the base of the column as they would be at the base of a keel stepped mast. The column needs just as much structure supporting it and spreading the loads as a normal mast step would. In either case, the downward force on the mast is enormous, on the order of two to three times the displacement of your boat. Imagine you have three sisterships piled on top of your mast, and with that in mind, take a look at the step and the way it ties into the hull structure. This is a very common problem area, as you have the mast compression and the weight of the keel pulling down, and the bow bending upward under headstay tension, water pressure, and slamming loads.

SST The whole area near the front of the keel and the base of the mast should be inspected for signs of movement, cracking, fatigue, or decay. Early fiberglass boats often had wood buried in the mast step or steel structures supporting the mast and keel. Many boats from the sixties and seventies are suffering from decay in those elements.

Chainplates

Chainplates are a notorious source of leaks and structural problems. The only chainplates that don't leak are composite chainplates, where the chainplate is an integral part of the hull/deck structure.

SST Often a chainplate is bolted to a plywood bulkhead. Guess where the bulkhead decays first? If you see discoloration or evidence of decay in the plywood near chainplate bolts, do not delay in repairing this area.

Whether the chainplate is attached to a bulkhead, knee or other form of support, this is another high load area and should be inspected for signs of movement, fatigue, or decay. Chainplates that fasten mid-deck without supporting structure are a waste of rigging wire.

Chainplates leak because shroud tension is very high and it is impossible to build a supporting structure that is entirely rigid. Therefore the chainplate is moving imperceptibly relative to the deck all the time. You need a sealant here that sticks well to both the metal chainplate and the surrounding deck (good luck), and is flexible to tolerate the movement. Your best bet is a good cover plate and generous application of 3M 5200.

SST The chainplate itself is usually very durable, but a close inspection is worthwhile. Look for any elongated holes or microcracking - which often reveals itself by a rust spot. Chainplates must be properly aligned with the shroud and toggle so that no rigging has any bend.

Hull/Deck joint

The best hull/deck joints are a Type PC attachment – they are permanently fiberglassed or welded together. No leaks, move on to the next paragraph. The rest are all type F – they rely on sealant and a row of fasteners to hold the joint together and watertight. The joint may be reliable and leak free for decades; but some boats will have a persistent leak or three, other boats are notorious for leaky hull/deck joints. If you have one or two annoying leaky spots you may be able to cure them by loosening local fasteners, perhaps gently prying the joint

open slightly and/or digging out bad sealant, and re-caulking. This is another good place for 3M 5200. The stuff is flexible and is a strong adhesive. It's not a joint you plan on ever taking apart again. If you have the misfortune of a boat with leaks all along the hull/deck joint, it's time to head to the boatyard. They may have to take the whole thing apart and rebuild, or perhaps it can be glassed over.

Companionway (OSR 3.08)

Very few boats have a watertight hatch for a companionway, almost all have a closure that will stop most of the water if a wave inundates the boat; but would leak rapidly if underwater. This is a Type O – a downflood location. Some boats have two companionways, one on each side of the boat. This may look cool; but the leeward companionway will be a lot closer to the water when you are knocked down. Similarly, some boats have very wide companionways, which makes for easy access in and out, nice to carry spinnaker bags through; but you need to be sure the lower edge of the companionway is well above the water when you are knocked down. Take it from me, there are few things scarier than an open companionway with 3 inches of freeboard when your boat is pinned on its side.

Sections of OSR 3.08 relate to companionways that extend below the local sheerline. Briefly, such a companionway is not allowed if you have an open transom, and if you have a closed transom you must be able to block the companionway up to that level. This is to prevent a filled cockpit from draining into the interior.

The faster your boat is, the more important it is to have good water protection from solid water coming over the housetop. Experience at sea sailing the boat hard will let you know if you need to improve the protection in this critical area. A leaky companionway can make for a miserable ocean voyage.

Hatches & Ports (OSR 3.08)

OSR 3.08 has some excellent rules defining where opening hatches are allowed, where they are allowed to open inward, etc. An opening hatch would be considered a downflood point. In some cases it will be prudent to fix them so they cannot be opened at sea. Refer to the section on stability.

Almost all fixed ports are either acrylic (Plexiglass) or polycarbonate (Lexan). They are very similar in strength and stiffness; but acrylic is somewhat more brittle and more vulnerable to scratching. If the window has compound curvature it needs to be vacuum formed - an easy process with acrylic, a difficult process with polycarbonate. Proper bedding and sealing of a fixed port is a bit of an

artform. Start with a good sealant. GE SCS2000 SilPruf is an excellent product for this location. Many ports are held in with nothing else. It is worth noting that commercial hatches rely on nothing but adhesive to hold the plastic port to the frame. Fasteners may be helpful to prevent a window from coming completely off; but fasteners are often a source of cracking, especially with acrylic. Fastener holes through fixed plastic ports must be overdrilled to allow for expansion, contraction, and deflections of the superstructure.

Leaky hatches are a major annoyance, and opening hatches have two seals to worry about – there is the seal in the hatch itself (Type MS) and the seal between the hatch and the deck (Type F). The hatch seal will depend on the hatch quality and service rating. We are talking about an ocean voyage here. A hatch rated for serious ocean travel is strongly recommended, especially for fast boats where the deck will often be awash and sometimes under solid water. The type F seal is in the hands of the installer, either the builder – or you if you are re-installing a leaky hatch. Use plenty of high quality bedding compound, set the hatch in it carefully. Tighten the fasteners lightly, say finger tight. Wait for the sealant to cure. After sealant cure, tighten the fasteners again, using a zig-zag tightening patterns as you would lug nuts on a wheel. Another technique is to put down a series of dots of the sealant and let them cure overnight. They will act as a spacer so when you fit the hatch the next day with a full layer of sealant, the goop won't all squish out.

Vents

Vents are not as leak prone as hatches because they usually incorporate a water trap; but are similar in that they are a downflood point. See the paragraph on downflood points; and decide before your voyage whether you want to fix the vent closed or establish a crew routine for closing them in rough weather.

Tank fills and tank vents

Tank fill fittings and vents are a Type F fitting and carry no load; so they are not usually a source of leaks. Tank vents, however, are by definition open to the interior of the tank. I once sailed a race to Hawaii on a boat where the water tank vent was located in the hull just below the sheer line. We discovered after the first night of sailing that one of our fresh water tanks had been contaminated with salt water coming in through the vent line. Half our water supply was gone overnight. It can be difficult to find a good location for tank vents. You don't want to smell the fumes from either fuel or holding tanks. You don't want sea water getting into any tank during a knockdown. Know where your tank vents are located and relocate them if the current place poses a risk.

Deck hardware

Murphy's Law and personal experience say that if you have done a careful job of bedding all the deck hardware, only one fitting will leak, and that will be above your berth.

Deck fittings, like chainplates, are more prone to leaking due to the loads that they carry. The first step to preventing a leak is to mount them strongly so that they won't move, which has a secondary benefit in that they won't rip out of the deck that way. This is more of a problem with modern race boats built with sandwich construction and thin skins. Fasteners should have generous diameter bushings through the core; and anything highly loaded like a winch, turning block, sheet jammer, or padeye should have a G-10 or other backing plate.

The next step is to bed the hardware with a good layer of quality caulking, making sure it gets down into the holes and blocks the path of water along the threads. Silicone sealants or polysulfides are a good choice for deck hardware. Avoid 3M 5200 here unless you are sure you never want to remove the part again. 3M 4200 would work well. One useful thing to know, most polyurethanes *require* moisture to cure, so getting a completely dry surface is not necessary. Some of them even require a damp surface for proper cure.

Control line openings (OSR 3.02.1, 3.09.2)

Control lines that lead under deck have become rather common on race boats. Very nice, keeps the deck clean and clear, free of tripping hazards. Unfortunately, unless they run through a sealed tunnel they are a downflood point and in violation of the safety regulations, which I will paste here to emphasize my point:

3.02.1 A hull, including, deck, coach roof, windows, hatches and all other parts, shall form an integral, essentially watertight unit and any openings in it shall be capable of being immediately secured to maintain this integrity.

3.09.2 Cockpits must be essentially watertight, that is, all openings to the hull must be capable of being strongly and rigidly secured.

Anchor lockers & hawse holes

It's common for cruising boat to have an anchor well in the bow, often with a nice big hawse hole to let the water flood in. Anchor hanging on a bow roller, windlass, big pile of chain; understandable. Secure anchoring is important to a cruiser and nobody enjoys carrying a chain and anchor around – but if you are going to be at sea without the possibility of anchoring for the next week or two,

you might want to get that weight off the bow. But that's not the point of this paragraph. You don't want that anchor well filling with water every time you put your bow into a wave. I've seen boats racing where the anchor well was draining continuously for minutes at a time. Give some thought to improving the seal on the hatch and add a cowling or flaps over hawse holes and drains.

Getting the Water Out

I want to share a secret with you: not everything in life works out the way you hope or expect. Let's say you have done everything in this article, your boat is the finest design from the most skilled builder. It goes without saying that your boat has the world's most excellent owner. Everything is exquisitely maintained and in perfect working order – yet somehow *water is getting into the boat!* Let's figure out how to get it back in the ocean where it belongs.

Bilge pumps and buckets (OSR 3.23, 3.09.3, 3.13.4-6)

Every boat is required to have two buckets. There is nothing like a bucket and a scared man for getting the water out. The good and the bad thing about buckets is they have a multitude of uses. Be sure you still have them available if needed in a crisis. I am sorry to admit that boats I have sailed on have contributed several buckets to the Pacific gyre. They get lost when they are ripped out of your hand as you try to clean them. They get lost when a seasick crew member leaves one in the cockpit and it is washed overboard. Consider carrying more than two; and make sure they have a good lanyard and a strong handle.

You are also required to have two bilge pumps permanently mounted, one in the cockpit, one below. Make sure the hoses reach the compartments you need to bail. Test the pumps! I sailed one boat for three years before I tried to use the bilge pump after hosing out the bilge. The pump was mounted backwards and was pumping into the boat! Make sure your bilge is clean and all limber holes are unclogged. I sailed on one boat where brushing your hair below decks was forbidden. I heard of another that found the limber holes clogged with blue fleece.

Final tip, a small portable hand pump is a wonderful addition to your kit – and plenty of good sponges.

Summation

Know your boat. Common sense and logic will go a long way toward understanding the potential for problems and finding solutions. You can learn and accomplish a lot by surveying the boat yourself. When in doubt, seek professional help from a marine surveyor, naval architect, or other marine specialist. And remember to *keep the water out of the boat!*