How safe is your rudder?

Megawat, a Hanse 371, sank in the Irish Sea in 2005 after the rudder stock broke, rupturing the hull (see PBO 464).The official report said possible factors include a retrofitted autopilot and rough machining and corrosion of the aluminium stock.

Emergency Steering

1. First priority is make sure you are not rudderless
   - As important as hull integrity, standing rigging & mast!
   - Rudder failure is a serious emergency

2. But know how to steer without a rudder
   - Incidence of mid-ocean rudder failure is about 1%
   - Lying helplessly abeam to a large swell is perilous
   - Self reliance is a must

Rudder Losses in Vic Maui

1992: Ajax (Santa Cruz 40)

Rocket J Squirrel (Swan 39)

Foxfire (Kaufmann 44)

2008: Something Wicked (Beneteau First 40.7)

2014: Anduril (Farr 395)

Multiple years: steering cable failures

Why Rudders Fail

1. Groundings
2. Collisions with floating objects
3. Construction errors
4. Fatigue (load cycle & material property dependent)

Ways Rudders Fail

1. Stock failure
   - Material fatigue with repeated and reversing torsion stress
     - More rapidly if loads near ultimate strength
   - SS suffers when deprived of oxygen (inside rudder tube with stagnant seawater)
     - Corrosion if oxide film on shaft removed by contact with solid bearing surface
     - Composite may be overstressed if given a severe hit but may not show damage
     - Breaks rather than bends

Ways Rudders Fail cont'd

2. Bearing failure
    - Grit trapped inside rudder tube abrades SS stock, resulting in corrosion
3. Framework failure
    - Corrosion of welded internal web from water trapped inside rudder
4. Delamination
    - Water inside foam-cored rudder in fibreglass rudders can delaminate the skin from the foam

What is hiding inside Your Rudder?

Potential Problems:

- Corrosion
- Bad workmanship
- Faulty design
- Inferior materials

Spade rudders are more vulnerable than skeg-hung (large loads at lower bearing)

Most common failure is stock breaking where it emerges from hull

Know Your Rudder System

1. Be familiar with primary steering gear, control cables (or gear system), linkages, and pulleys or sheaves
2. Designate some crew to have extensive knowledge of steering system

Preventive Maintenance

1. Service and inspect all components prior to the race
    - No worn, misaligned, or fatigued parts
    - Lubricate
    - Inspect & service rudder stock bearings
    - Examine stuffing box, lip seals or rubber gaiter while moving at hull speed (If rudder tube is not well above waterline)
    - Vertical alignment (spade rudder must rotate in place)

Preventive Maintenance cont'd

- Ease of rotation stop to stop
- Strong stops prevent rudder movement beyond about 35^0
- Drill 1/8" holes in rudder blade & check for rust-coloured water
- Examine edges of blade, especially at top where stock enters it
- Drop rudder a few inches to inspect at lower bearing
  - Perhaps use non-destructive sonic testing

Note 1: Consider using professionals for pre-race PM

Note 2: See Appendix A for checklist for Wheel Steering System inspection

Preventive Maintenance cont'd

2. Take spares (e.g.; cable/kevlar line, linkages)
   - Ensure have required tools
   - Location on Safety Equipment Chart
3. Regular inspection while racing

Preventive Maintenance cont'd

If rudder condition in doubt, it may be cheaper to replace than risk losing it on the high seas

1. Subjecting a material to repeated load cycles will weaken it with time, and will do so all the more rapidly if those loads approach its ultimate strength
2. In practical terms this means that marginally spec'ed stock will fail before a stronger one and that all of them will weaken with time

Training Before Race

1. At crew meetings discuss scenarios if rudder is lost
2. Practice inspections in uncomfortable seas
3. Ensure more than one crew are knowledgeable about steering system
4. Reinforce role of Person in Charge and rest of crew in case of incident

Good Seamanship

1. Sail balance
2. Gear down in heavy weather
3. Avoid putting a rudder hard over to prevent a broach to avoid ‘dynamic stall’
4. It’s a long way—don’t overstress the rudder

OSR 4.15.1 a)

"Except when the principal method of steering is by means of an unbreakable metal tiller, an emergency tiller capable of being fitted to the rudder stock"

Note: Ensure emergency tiller for rudder actually works & location is on safety equipment chart

- Tight fit (no play)
- Try it while underway

OSR 4.15.1 b)

1. “Crews must be aware of alternative methods of steering the yacht in any sea condition in the event of rudder loss”
2. “At least one method must have been proven to work on board the yacht”
3. “An inspector may require that this method be demonstrated”

INTERPRETATION No 1/2004 - Emergency Rudders

OSR 4.15b) does not necessarily require an emergency rudder

Key is for an effective alternative method of steering to be devised and tested so that a method is developed which is most suitable for each yacht and crew.

Design Considerations for Emergency Rudder

1. Type of failure of primary rudder (clean break or bent rudder stock)
2. Ease of steering - it has to work
3. Anticipate going a long distance & high sea state
4. Must work with storm jib and trysail
5. Attachment method to the hull--how will you install the rudder while at sea
6. Stowage – safe storage of emergency rudder when you're (hopefully) not using it
7. Know the forces (1’X4’ blade at 7 kn = 1666 lbs)
8. Blade size (underwater surface area)

Examples of Emergency Rudders

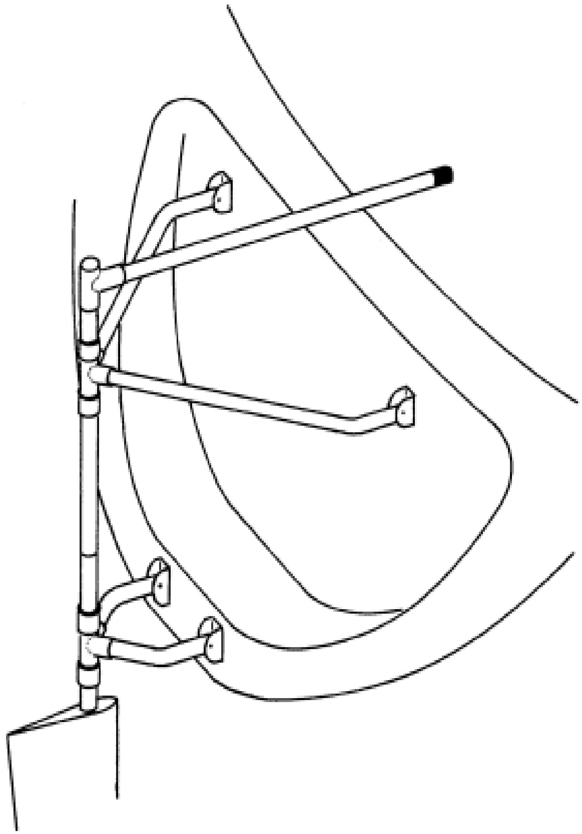
SOS Rudder from Scanmar

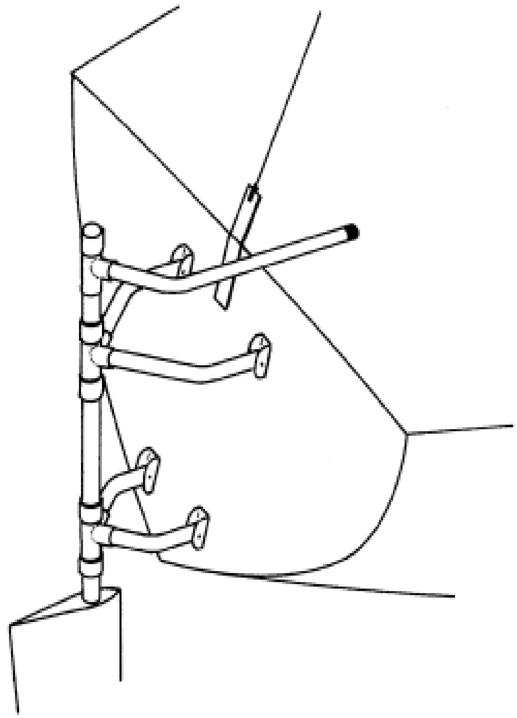
"The SOS Rudder is an emergency steering system designed to get you to the nearest port in case of rudder failure. DO NOT ATTEMPT TO CONTINUE TO RACE, OR TO CARRY A HEAVY PRESS OF SAIL"

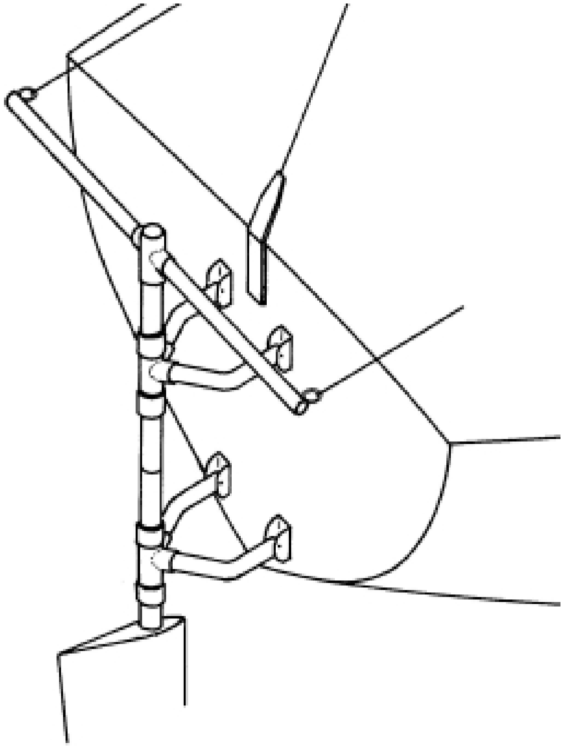

FIRST
40.7

SOS Rudder

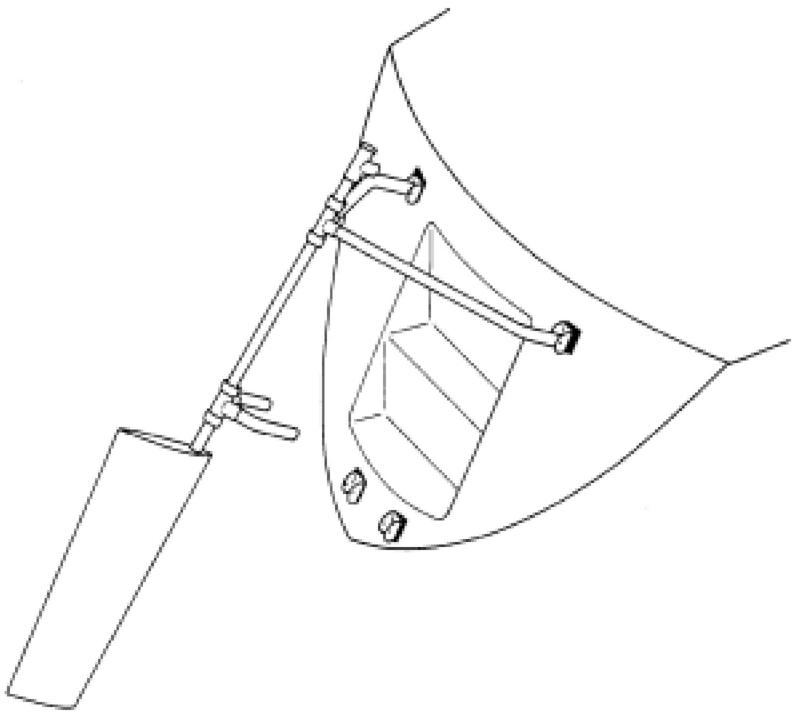
Three Steering Configurations

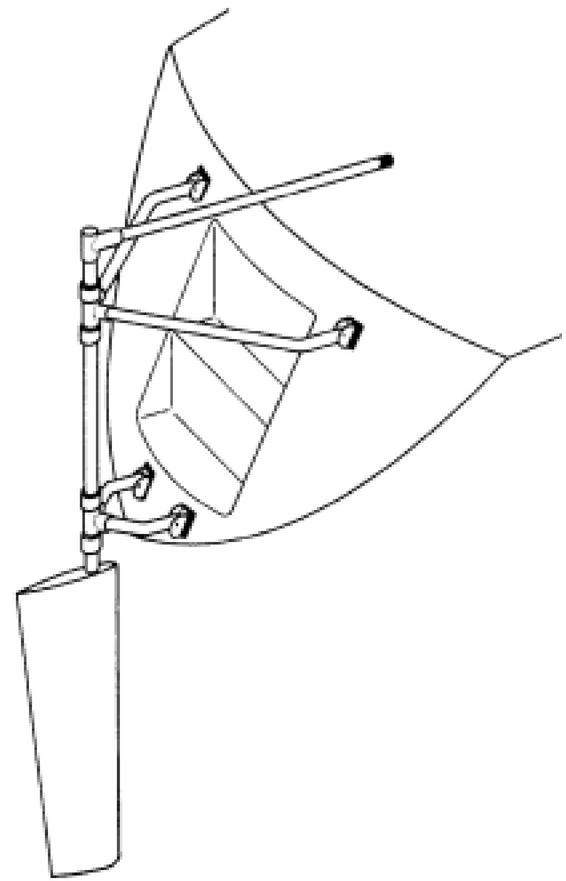






Installation



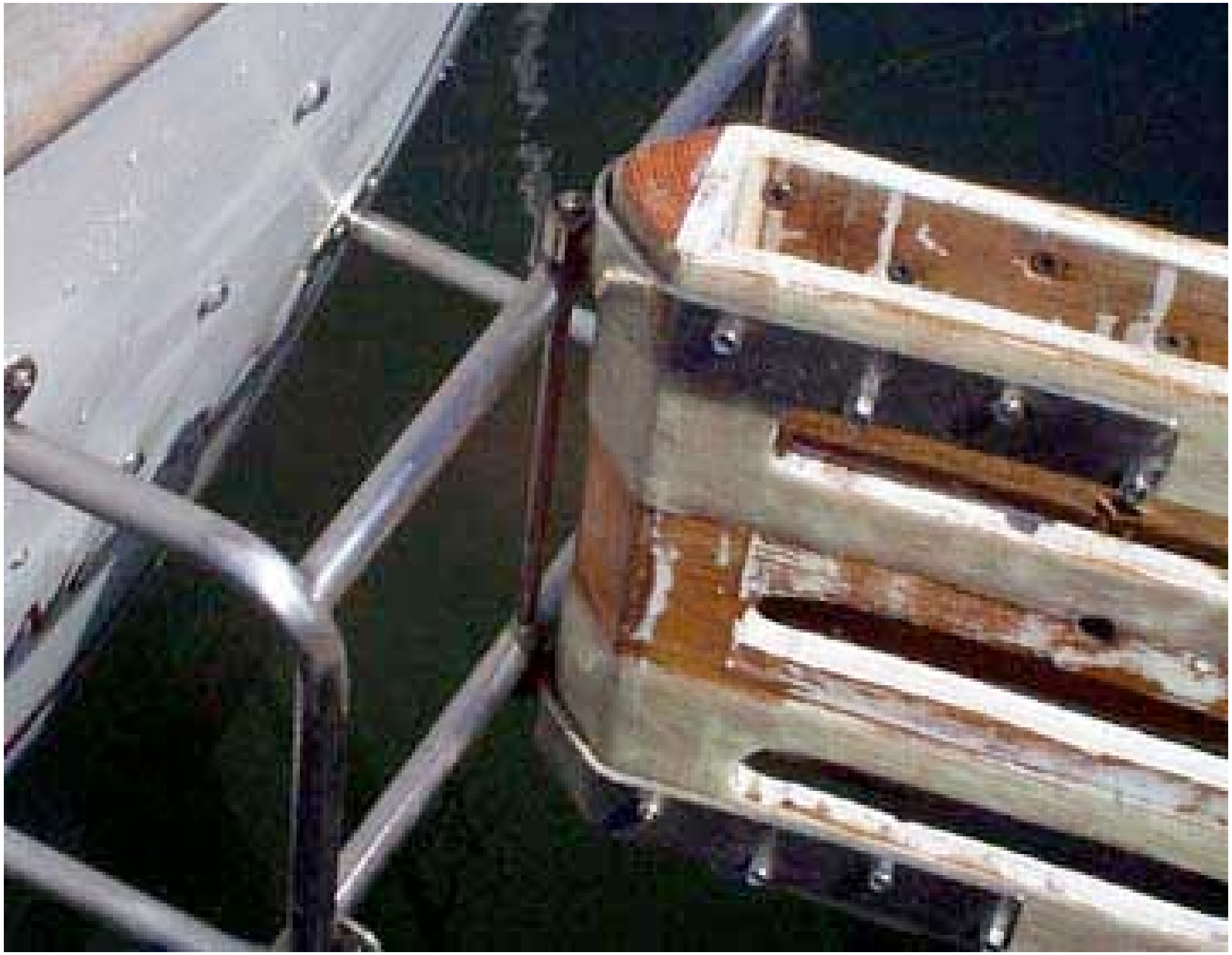


Three Point Framework to Hold Pintles and Gudgeons

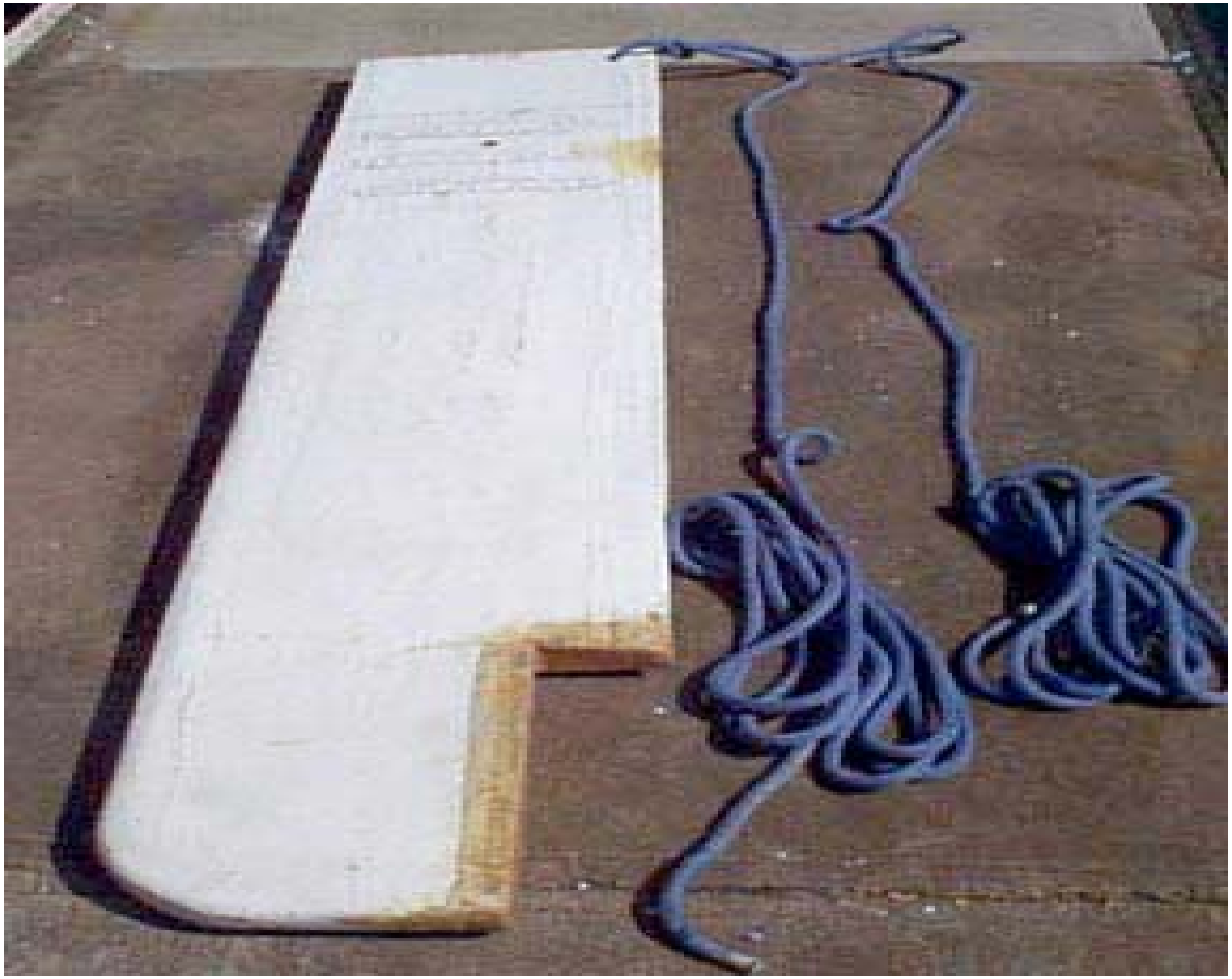
Three Point Framework to Hold Pintles and Gudgeons

Hanging off the back of the boat to install this rudder in any sort of sea state would be difficult and dangerous

Rudder in a Cassette System



Rudder for Cassette



Rudder in Cassette

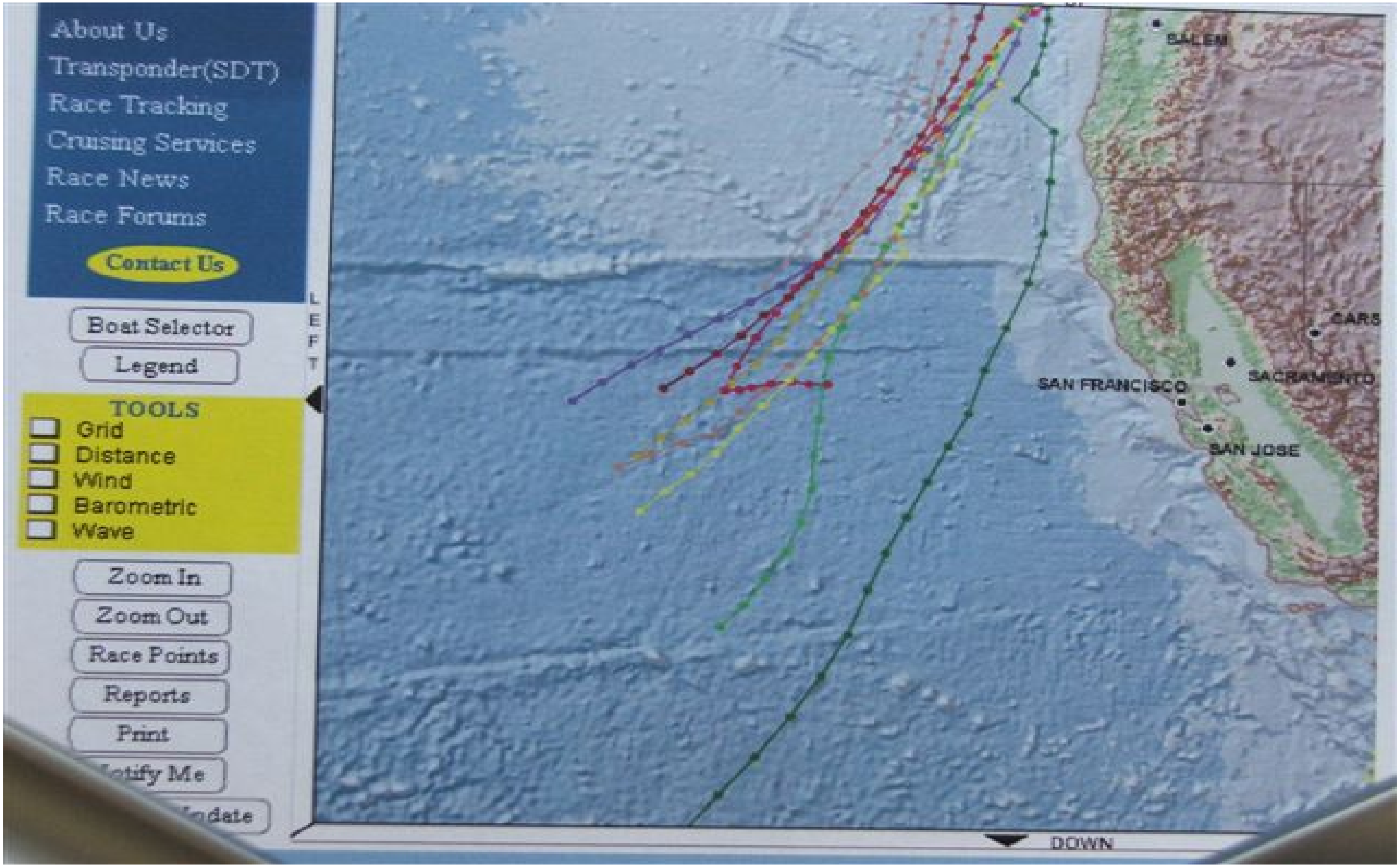
Hydrovane

http://www.hydrovane.com/

Random Thoughts

1. If rudder is intact use autohelm during repairs (e.g., steering cable break)
2. Windvane may work but may be too small if main rudder is lost
3. Plywood clamped to Spinnaker pole with U bolts won't work
   - Need over 100 pounds force on tiller end & wear and damage at fulcrum
4. Be wary of one-off designed and built

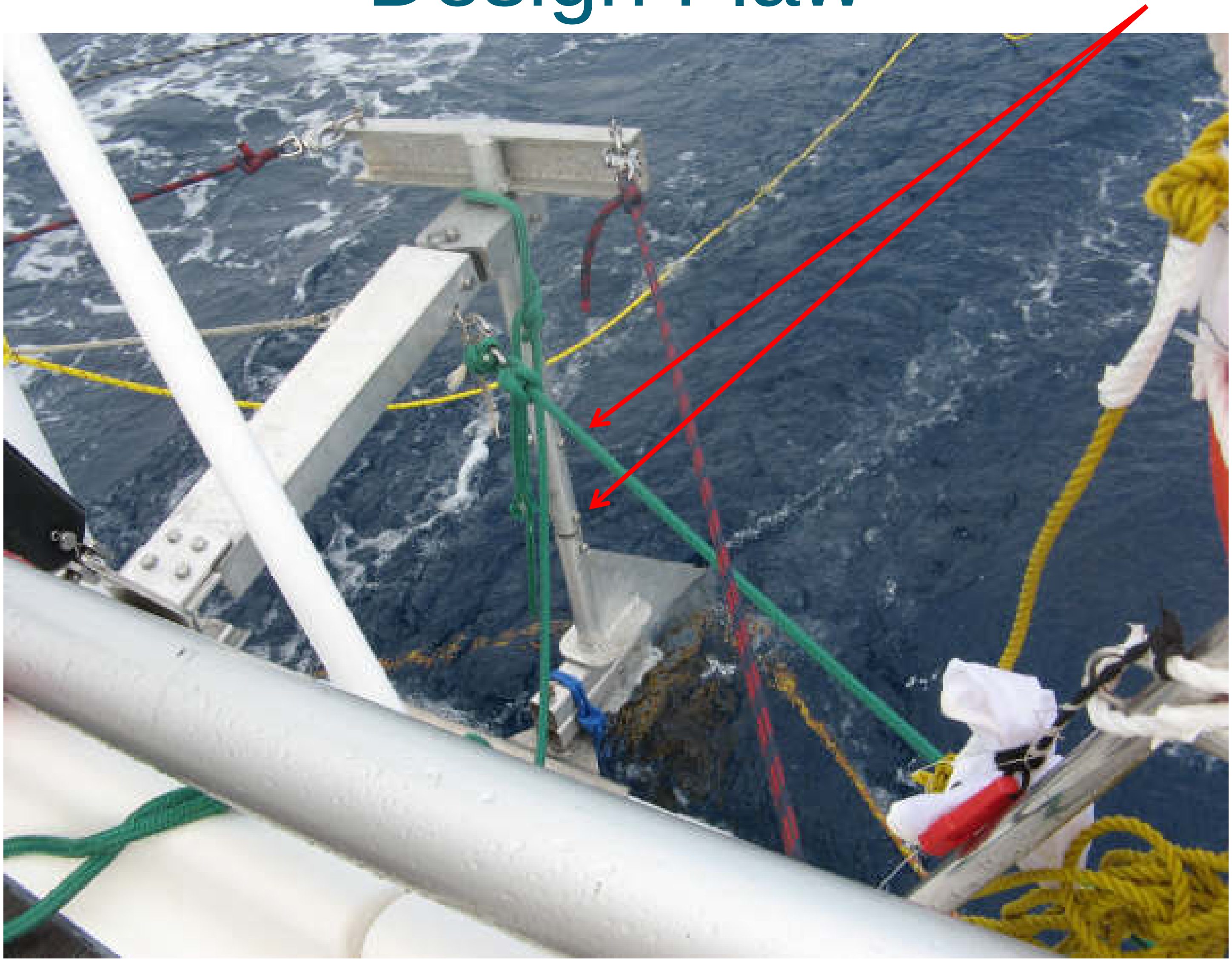
“It” Can Happen



Something Wicked, Beneteau 40.7

Clean Break

Design Flaw



Hana Mari

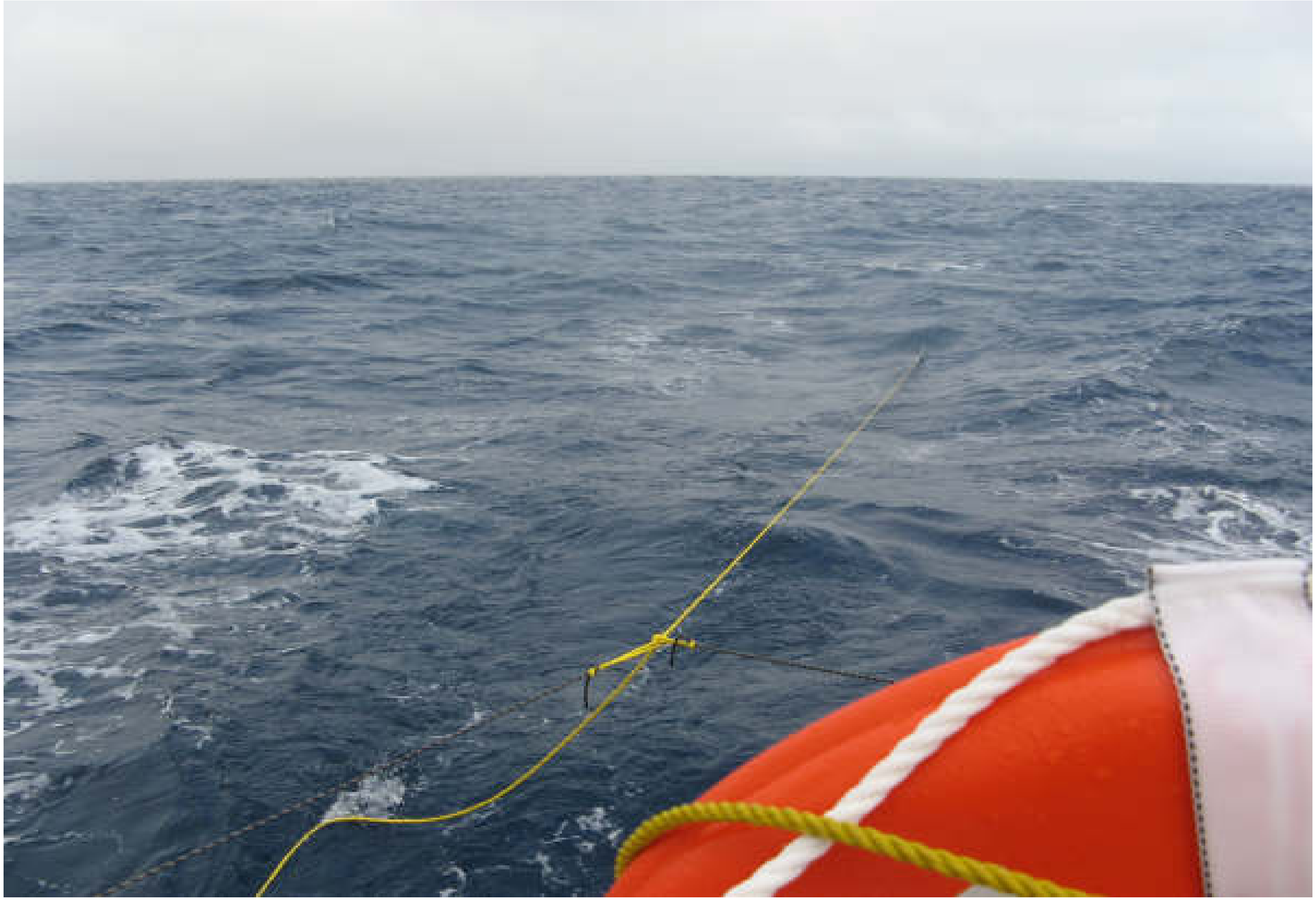
(Light winds, no seas)

“Torsion loads on the frame were immense and caused the welds to fail. This was under power at < 3 knots”

Steering with Drogue

Spinnaker Pole Lashed to Pushpit

Steer to Starboard

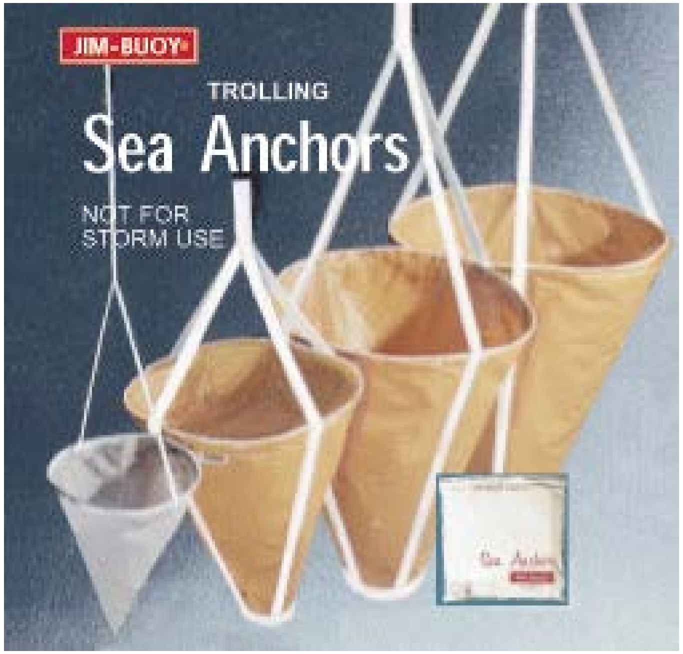


Steer to Port

Drogue for Emergency Steering

- ➢Manufacturer: Jim Buoy
- ➢Model: 926 (18" diameter)

http://www.jimbuoy.com/pages/marine/anchors.htm



Seven Things

1. Don’t underestimate the forces on the rudder

- (3,750 lbs on 9 sq ft rudder at 16 knots)

2. Inspect and service all components of steering system
3. Money is well spent dropping and inspecting rudder stock
4. Emergency rudder must work in strong winds and high seas
    - Must steer boat with or without wind, whether or not yacht’s rudder is still in place

- Be wary of one off designs!

5. Plan how you will install emergency rudder at sea
6. Take a drogue appropriately sized
7. Use a spinnaker net—most steering failures occur downwind

SWIFTSURE

Hosted by the Royal Victoria Yacht Club

VIC·MAUI

VIC-MAUI QUALIFYING RACE

Swiftsure International Yacht Race, May 28 – 30, 2016

Vern Burkhardt, Chair

Appendix 1: Checklist for Inspection of Wheel Steering System

Inspection of Wheel Steering System

When the boat is hauled for its annual service a good external inspection is in order:

1. **Of the rudder assembly**
   - Check for external damage to rudder blade particularly at the bottom
   - ensure rudder has not taken on any water
   - sound with a small hammer to check integrity
   - check for corrosion bleeding out, indicating signs of water intrusion and possible crevice corrosion internally
   - condition of rudder post visible between blade and hull
   - make sure rudder is not bent

   NOTE: To take things one step further, the rudder may be removed for a more thorough inspection of the rudder post and non-destructive sonic testing can be done to check the integrity of the post

2. **At the steering pedestal**
   - check condition of wheel and make sure there is no excess play between pedestal shaft and wheel, and that retaining nut is tight
   - check wheel brake operation
   - check wheel pilot assembly if equipped. Make sure it is securely fastened to wheel and drive belt is in good condition
   - move wheel from lock to lock and check for smooth operation with no unusual sounds

Inspection of Wheel Steering System cont'd

3. **Inspect rudder post packing gland assembly**
   - Adjust if necessary

4. **At the steering quadrant**
   - inspect steering cables for broken wires within cable, especially at wear points
   - inspect condition of steering chain
   - make sure cables are adjusted to correct tension
   - inspect cable clamps and make sure they are installed correctly and are tight
   - inspect quadrant assembly and fasteners
   - inspect condition of sheaves and make sure there is no excessive wear on pivot shafts and sheave bores
   - make sure cotter pins are all in place

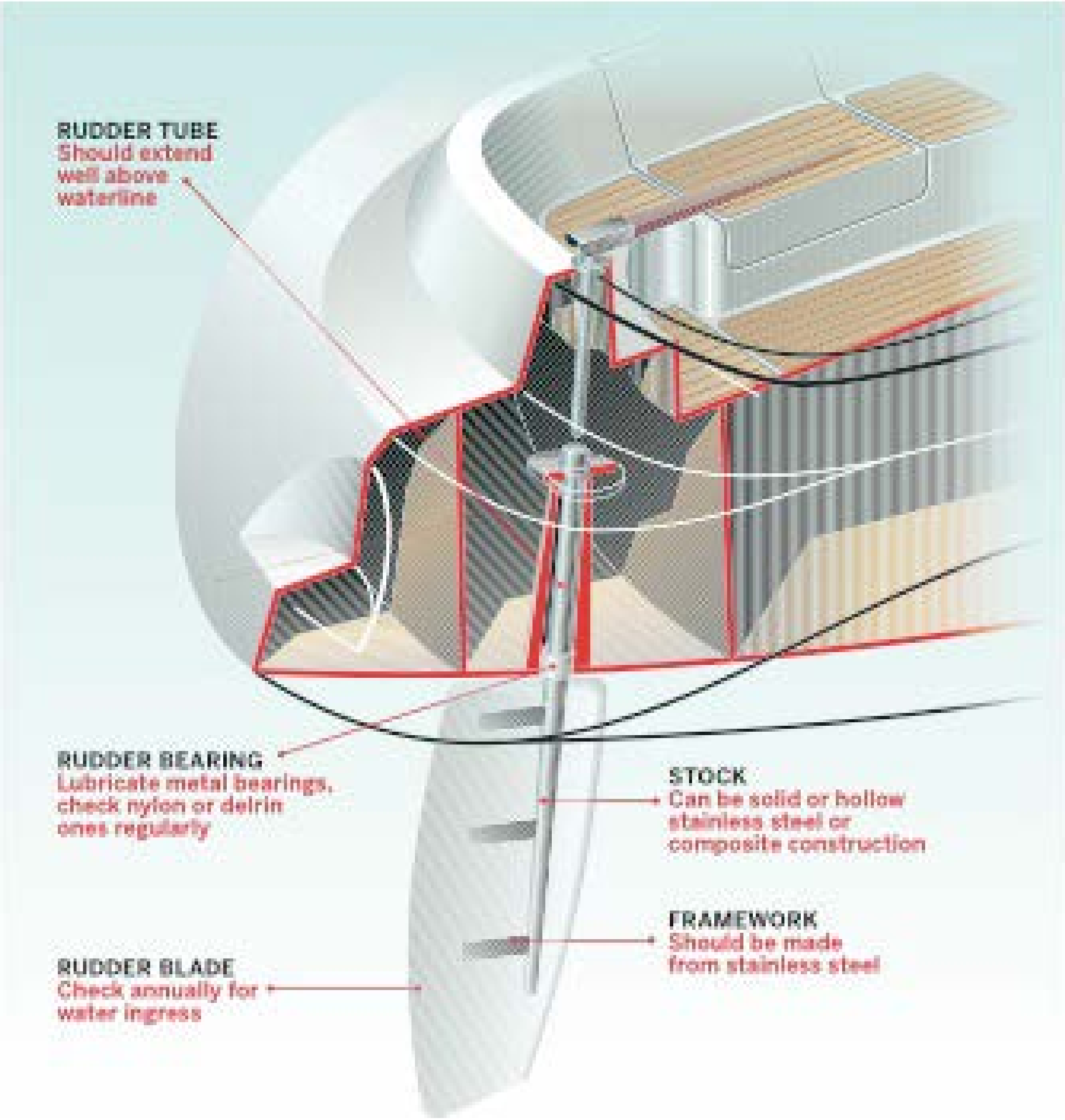
5. **Inspect fittings and attachments to hull or under deck**
   - Inspect for signs of cracking or delamination of any attachments to the hull or other supports for steering components under the deck (e.g.; for bases of sheaves)

6. **Inspect autopilot assembly if equipped**.
   - Make sure actuator is securely fastened and connection at rudder post or quadrant is secure

Generally a pair of eyes is your most valuable tool for inspection!

Credit: Based on advice from Stan Coppen, Technician at Canoe Cove Marina in Sidney BC

Appendix 2: Cross section of Spade Rudder
and
Force on Rudder



RUDDER TUBE
Should extend well above waterline
RUDDER BEARING
Lubricate metal bearings, check nylon or delrin ones regularly
STOCK
Can be solid or hollow stainless steel or composite construction
FRAMEWORK
Should be made from stainless steel
RUDDER BLADE
Check annually for water ingress

Heavy Force on Rudder

F = A * Cl * 1/2 * RHO * V^2

F = force (lb)
A = area below transom (ft^2)
Cl = Coeff. of lift (use 3.0 to allow for pumping transients)
RHO = density of water (1.9905 slugs/ft^3)
V = design speed (ft/sec)
(1 knot = 1.6878 ft/sec)

F = 8.5 * A * V^2

F = force (lb)
A = area below transom (ft^2)
V = design speed (knots)

Example: 1 ft. x 4 ft. blade, 7 knots: F = 1,666 lb