WHEEL, THROTTLE, AND GEARSHIFT ...WHY THINGS HAPPEN THE WAY THEY DO—WHETHER YOU WANT THEM TO, OR NOT.

By Bill Baldwin

You've carefully set things up to bring your venerated runabout onto the dock perfectly; done everything; thought of everything. This one's gonna' be a greaser for sure. Then, without warning, you realize you're moving too fast; you're caught with full right rudder, and the stern's drifting left toward the dock like it's on ice. All of a sudden, you're only along for the ride. You try everything, but the forces are more than you can control… WHAM! BAM! [Editor's Note: In order to preserve the family orientation of this publication, the remainder of the paragraph has been deleted due to violent content and language.]

Another faultless varnish job bites the dust as that gleaming mahogany showpiece ignores all inputs to helm, throttle, and gearshift, then gleefully gores itself on the *one* place at the dock that is capable of defeating rub-rail protection supplied by the best marine designers of the antique and classic boat world. Of course, this happens before an audience made up of people who *never* show up when you glide onto a mooring like you've been doing it all your life (even if you actually *have* been doing it all your life).

Just what is it that lets people make perfect landings every blankety-blank time? What right do others have to back a Riviera into a slip as if it were a Buick? Why do some people's boats look if they just came off the production line—in spite of frequent operation in adverse wind and waves?

The rest of us mere mortals (with our scratched and battered boats) would love to dismiss these talented Skippers as people with more luck than skill, but we simply can't. They operate with focus, skill, coordination, and—most importantly—an inherent connection to the implacable principles of physics governing all boats with rudders and single, non-pivoting propellers. Probably the biggest difficulty about maneuvering our old boats and their "traditional" propulsion systems is that the only directional control we have is pivoting the stern left or right. In case anybody hasn't yet noticed, steering a boat forward only *seems* like driving a car, but any resemblance to following a couple of wheels that reliably lead a chassis right or left is only a dangerous dream. And in reverse, most of the time, no matter which way we turn the steering wheel, we can only pivot the stern to the left. Aside from that, we can make them go forward or backward, but that's it. Worse yet, unless we hit something or let them glide to a halt, the only way to stop is to throw the propeller into reverse—with all the trouble *that* causes. It's a difficult life we suffering Skippers lead, and there's not much we can do about it because our problems are caused by largely immutable principles of physics. Here's what we're up against:

SIDE FORCES—BLAME THE PROPELLER

Most basic maneuvering problems are caused by unexpected Side Forces that pivot the sterns of our boats right or left, independent of how we've turned the steering wheel. Most of these are caused by the propeller—or at least the *effect* of the propeller—on the boat hull. The worst part about these forces is that there's not much you can do except deal with 'em. But that very art of dealing is what separates real boat handlers from the average klutz. Read on and weep!

Side Forces Underway

You'd think since propellers are designed to *propel* your boat, that turning one AHEAD (to the right) would cause the boat to move straight ahead, and that turning one ASTERN would cause it to move the boat straight astern. Oh no. That's the reason "pointable" stern drives and outboards are so popular these days. One of the biggest problems is that a propeller produces clearly demonic Side Forces in addition to thrust along the propeller shaft. These demons can be broken down into the following four elements: Following Wake Effect, Inclination Effect, Helical Discharge Effect, and Shallow Submergence Effect. They are (more or less) illustrated in Figure 1.

Pivoting the Stern Left

The *Following Wake Effect*, pivots the stern to the left and is caused by the hull dragging water along with it because of skin friction. The closer to the hull (high wake effect), the closer its velocity is to that of the hull. Farther below (low wake effect), the velocity slows. This dragged water is called the *frictional* *wake*, and starts out at zero thickness at the bow but can reach considerable thickness towards the stern—and the propeller. Within this wedge-shaped envelope of water moving along at different speeds, the propeller blades exert more torque when turned through regions of high following wake near the hull. With right-rotating screws, this tends to move the stern to left (causing the boat to veer to the right).

Pivoting the Stern Right

The three remaining demons attempt to pivot the stern right and your bow left. Together, they overpower the Following Wake Effect and insure that you nearly always have to apply a little right rudder to make your boat go in a straight line.

In addition to its fore-to-aft motion, the Following Wake Effect also has an upward motion aft that has an important effect on propeller behavior; this is called the *Inclination Effect*. As the propeller blades move downward (along the right side of their circular path), they meet water that is moving upward as well, increasing their thrust in this arc—and decreasing thrust on the upward, right arc. The effect is heightened because we incline the shaft upward so it can pass through the hull to the engine.

Helical Discharge from the propeller of a single-screw boat impinges directly on the rudder. That part of the discharge *above* the propeller hub creates a force that tends to pivot the stern to the right while the discharge below the propeller hub tends to pivot the stern to the left. Because of the increased blade angles of attack in the upper arc (due to the Following Wake Effect), the discharge from the upper half of the arc is stronger and the net effect tends once more to pivot the stern right along with the Helical Discharge.

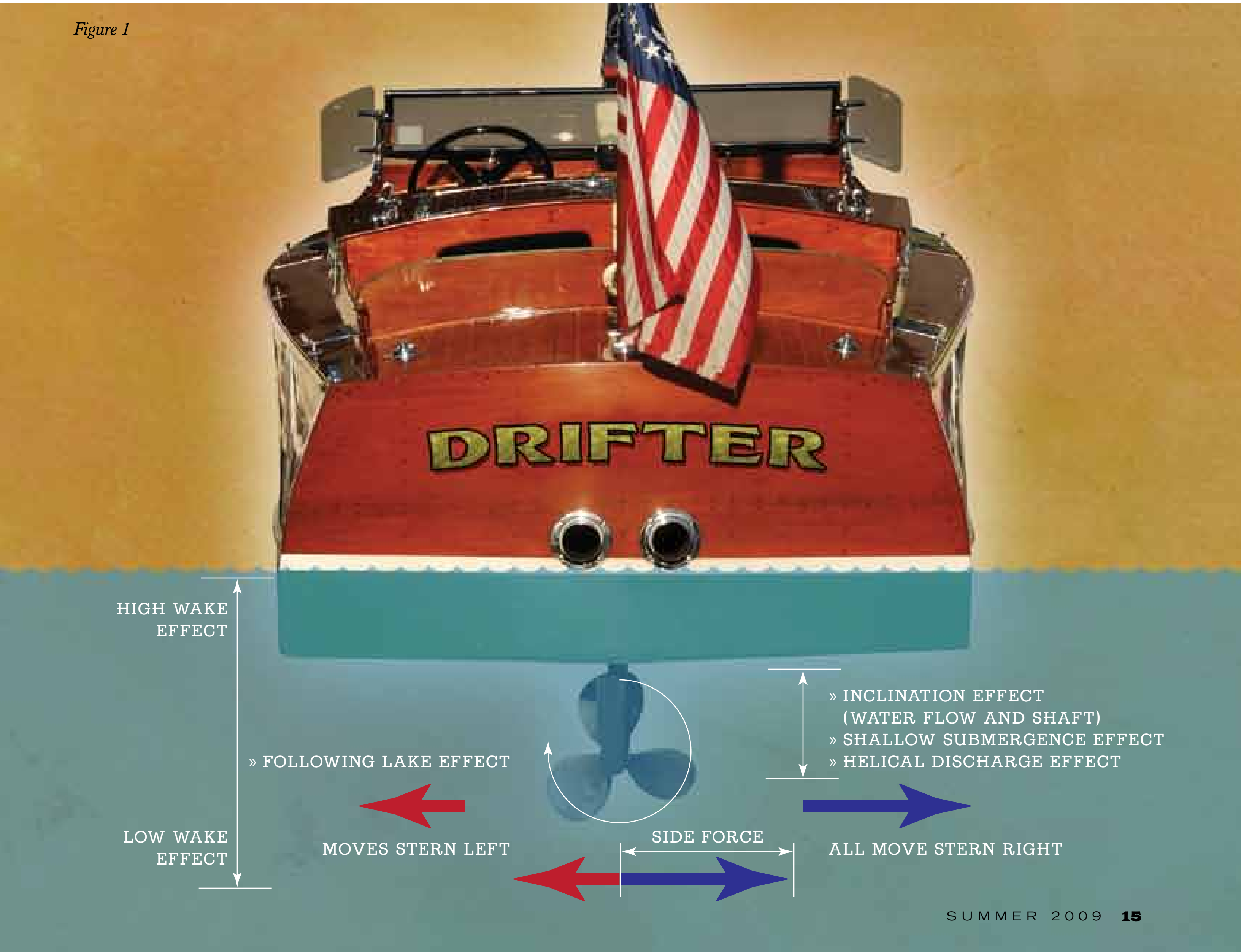
Finally, a *Shallow Submergence Effect* frequently draws air from the surface when considerable power is applied to the propeller and causes the blades in the upper arc to act as if it were in a less dense medium; thus also pivoting the stern right.

As mentioned above, all three of these forces completely negate the Following Wake Effect and what is left over becomes the diabolical Side Force.

Side Forces Starting Under Way

With your boat at rest or just starting to move, the stern usually pivots to the right. Why? Well, since the hull isn't moving, the Following Wake Effect is virtually nil. And since only the Shallow Submergence Effect is independent of the Following

Figure 1



Wake Effect, it's got to be responsible. Look at the water in the vicinity of the propeller when you watch someone start off rapidly. You'll see a churning action as air is drawn down into the propeller disk, even though the propeller is well below the surface, and sure enough, the stern will be pivoting to the right.

Side Forces When Backing

It's when you're in reverse that things really go haywire. When turning the propeller in reverse the resulting Side Force is now on the *other* side, pivoting the stern to the *left* this time.

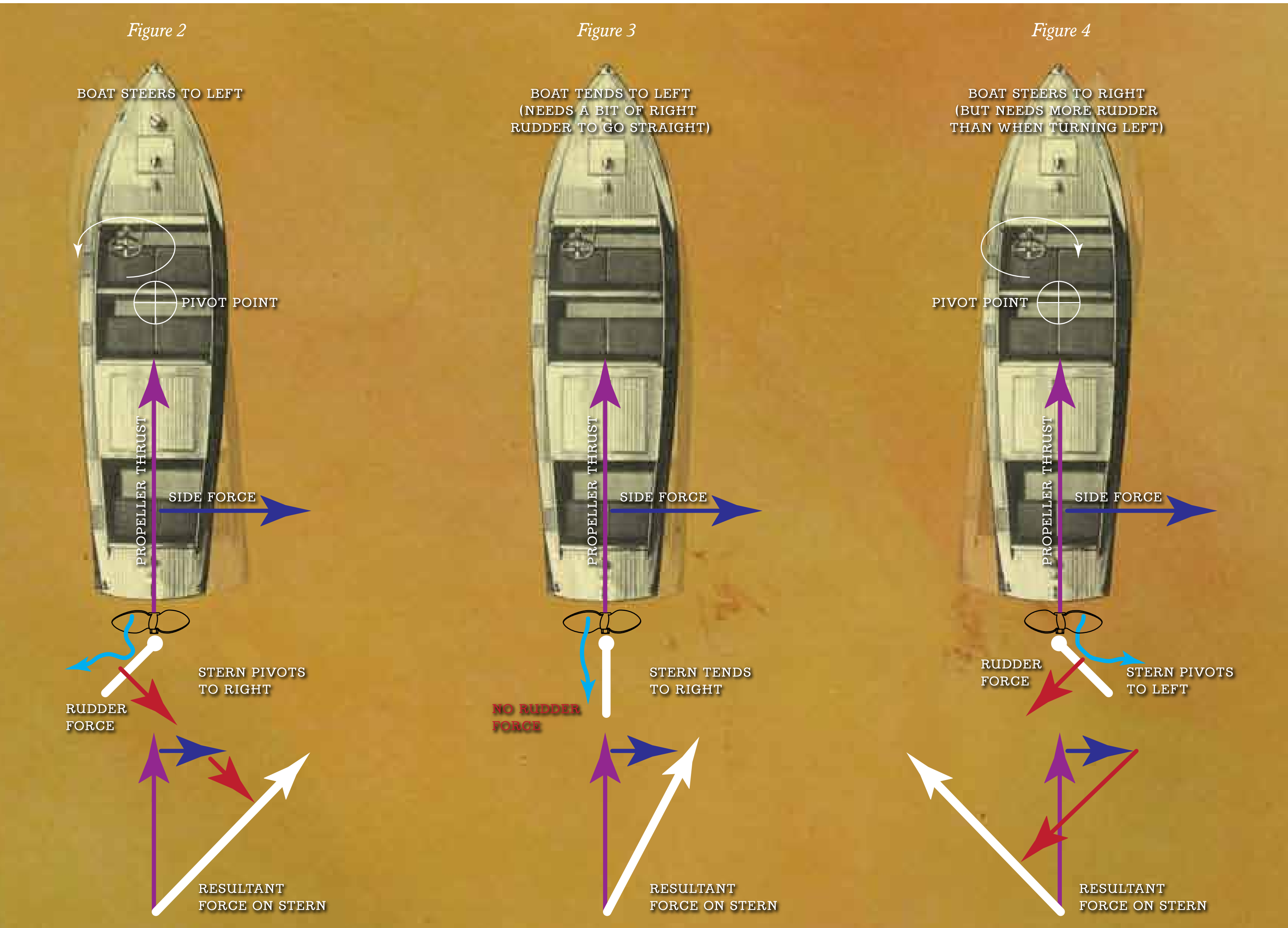
When you begin to back up with the boat dead in the water, the propeller is biting into undisturbed water; therefore there is no Following Wake Effect to pivot the stern right—and counter discharge from the propeller whose upper half tends to bank up against the right side of the counter while the lower half spills under the keel. The result strongly pivots the stern to the left. For this reason, it's necessary for a single-screw boat to build up appreciable sternway before the tendency to back to left can be overcome by use of the rudder.

RUDDERS: THE ONLY STRAIGHT SHOOTERS

Rudders are hydrofoils, designed to obtain a lift force perpendicular to the flow of water running past them. If they are swung to the left, this lift factor drags them to the right, and visa-versa—with no other side effects. Rudders also produce a drag force parallel to the flow of water that acts against the lift, so the turning power of any rudder is a resultant vector somewhere in-between the two forces. A most important thing for we single-screw Skippers to remember is that since rudders are mounted directly astern of our propellers, a large Rudder Force can be obtained from the propeller current flow as the propeller turns to move the boat ahead, even though the hull has not begun to move appreciably. Unfortunately, putting the boat in reverse from a standstill can cause only a very slight current to flow past the rudder, so no appreciable Rudder Force will be felt until the rudder itself is moving smartly through the water.

PUTTING IT ALL TOGETHER

Under our own power, we Stinkpotters steer boats by means of the three forces described above: Propeller Thrust, Side Force, and Rudder. And although we've considered them sepa-



rately, we've got to combine them if we're to predict what they do in concert.

If we define Propeller Thrust as the component of propeller action that acts in line with the propeller shaft (turning forward or aft), we can lump all other components of propeller action in the horizontal plane and call it simply, Side Force. Similarly, because the force on a rudder inclined to the flow is nearly perpendicular to its faces, we can define that force as Rudder Force. Next, since all three forces act at nearly the same place near the stern of a boat, we can, for all practical purposes, consider the combined effort as a Resultant Force. We Skippers do the controlling of our boats by knowing how to live with—and control—this Resultant Force.

Drawings 2 through 8 contain vector diagrams that vary combinations of Propeller Thrust, Side Force, and Rudder Force into Resultant Forces that can be used to predict which way the stern will pivot when we use varying combinations of propeller and rudder. Clearly, throttle settings impact the magnitude of most stern movements, and these has been left as an exercise for the reader.

In Forward Gear

Figure 2 shows what happens at the stern when you turn the wheel left as the propeller is turning forward. The stern pivots to the right because the combination of Side Force and Rudder Force, and the bow goes to the left—pretty much just like you want it to.

Figure 3 shows what happens when the propeller's going forward and the rudder is fore-and-aft. Even though your steering wheel is straight, the stern inexorably pivots to the right, and this is the reason you always have to run a straight course with a little right rudder (even though you adjusted the steering wheel to perfectly line up when the rudder is fore and aft).

Figure 4 shows why you've got to turn the wheel farther when you're steering right than when steering left. Even though the rudder is operating normally to pivot the stern to the left, the Side Force subtracts from it, making a lesser Resultant Force when you're steering to the left. Remember, we're not making this up!

In Reverse Gear

Figure 5 shows what happens when you turn the wheel to the left, then throw the gearshift into reverse. Note that there's

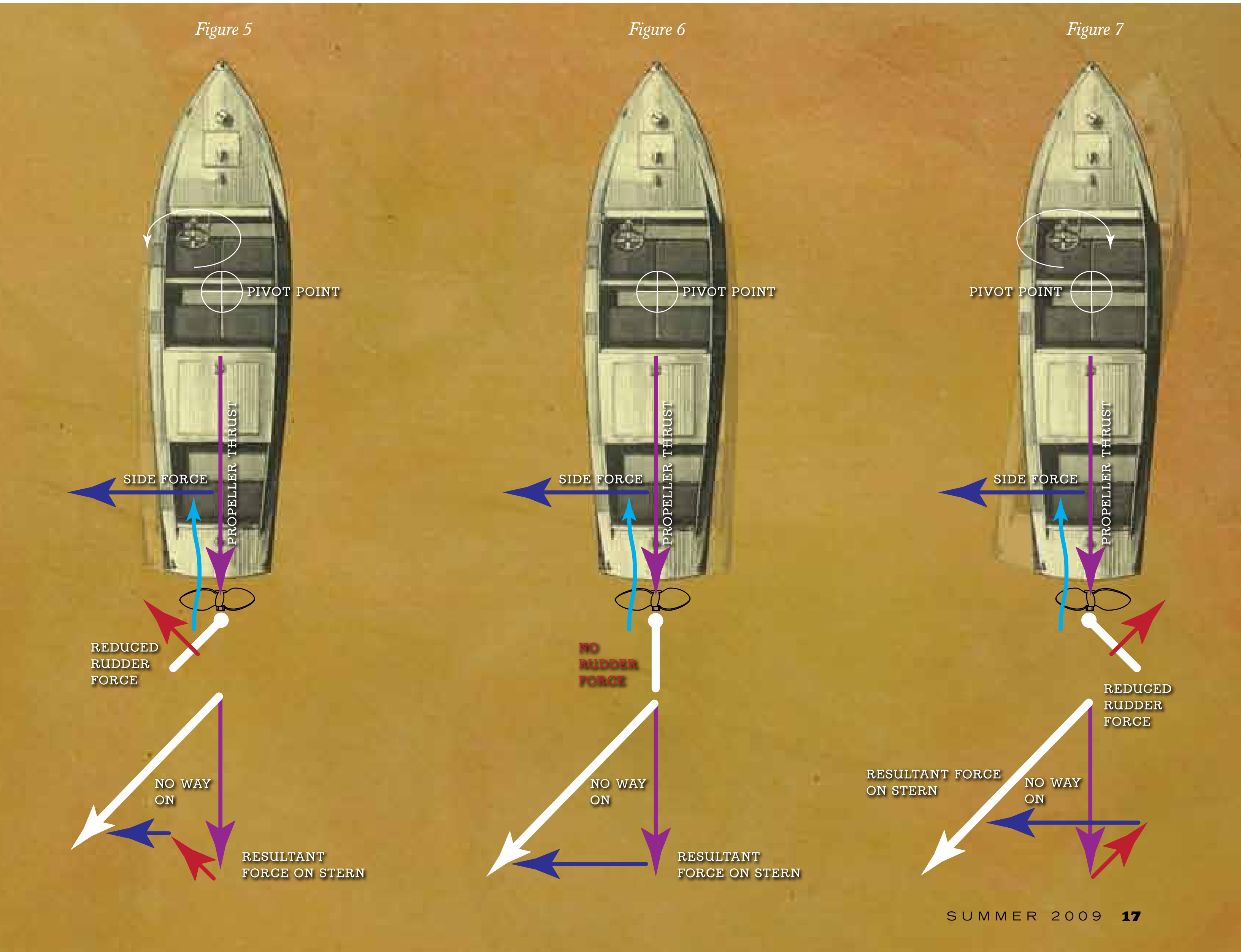
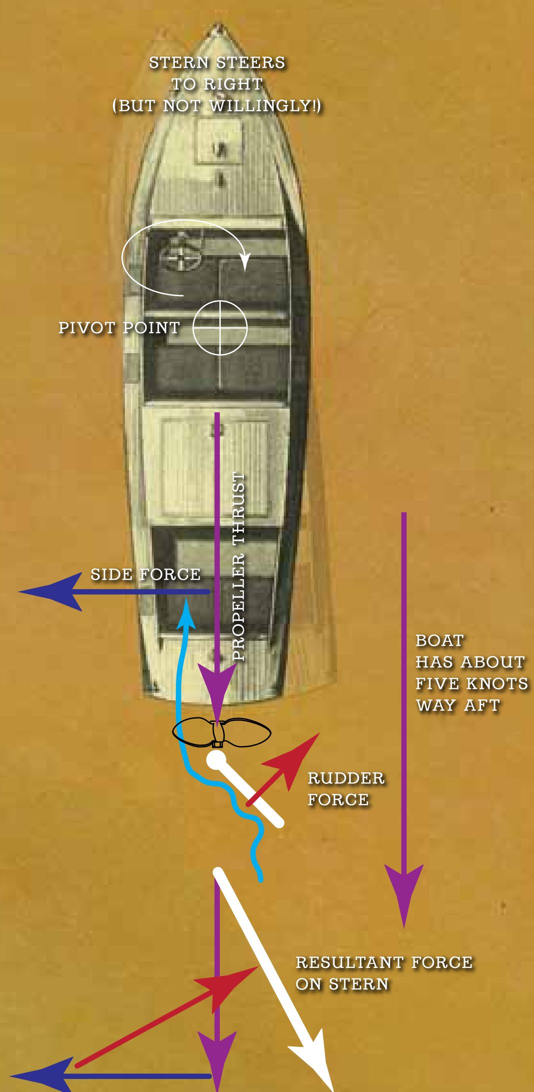


Figure 8



hardly any Rudder Force at all because no water is flowing along its faces—but the Side Force is now magnified. Why? Because the propeller is biting into undisturbed water; therefore there is no Following Wake Effect to diminish discharge from the propeller on the counter and the keel, and this magnifies the Side Force. The stern swings to the left.

If you have a few knots of forward way on, this is the easiest way to kill your forward motion and swing your stern smartly to the dock. Life would be so much easier if all docking situations were exactly like this.

Figure 6 shows what happens when you shift into reverse with the rudder in fore-and-aft position—pretty much the same thing, only less thrust to the left.

Figure 7 shows what happens when you turn the wheel all the way right, then shift into reverse. There's still not enough Rudder Force to deal with the magnified Side Force and… Surprise! Your stern still pivots to the left—proving once more that physics, *not you* is always master of the situation.

Finally, Figure 8, at left, shows what happens once you're underway in reverse. Now, you've got some water moving over the faces of the rudder and viola! The stern at last pivots to the right just as you wanted it to (if a bit grudgingly).

THE CONCLUSION

No matter what boat you're running, if it has a single, fixed propeller and a single, fixed rudder mounted astern of that propeller, it's going to handle according to the physical principles described above. All this varies, of course, with the configuration of your particular hull. But in most cases, the only variances will be in the magnitude of the pivoting—although it is true that in rare cases, some single-screw boats have a tendency to pivot right when moving ahead. How to handle all of this? First of all, know the physics of things so you can make at least half-accurate predictions of what will happen. Then, practice, practice, practice on your own, particular boat until you have a pretty good idea about the magnitude of the vectors that actually happen.

Finally, there will come a day when you can put that runabout on the dock every time—better, even, than Chris Smith, himself. Then just as you're about to impress a large crowd at the gas dock with your magnificent handling skills, the wind will come up, you'll be caught with full right rudder, and the stern will start drifting left toward the dock like it's on ice. All of a sudden, you'll only be along for the ride as your prized hat blows from your head. You'll try everything, but the wind will be more than you can control, and… WHAM! BAM!

Wind? That's a whole 'nother subject.

Basic principals of physics and drawing concepts compiled from: Crenshaw, R.S., Jr. (Captain, U.S. Navy, Retired), Naval Shiphandling*, Fourth Edition, Annapolis: Naval Institute Press, 1988. 13-47. All used with permission of the publisher.*