

Stability III: Heeling, righting moments

In the last installment of this ongoing series on stability (CFN September 2003, page 13B), we explored the relationship between the center of gravity and the center of buoyancy.

This time, let's look at the relationship between the forces of heeling and righting as we continue our effort to better understand how to avoid instability that can lead to capsizing.

Last time, we saw that the center of gravity shifts as the load shifts, while the center of buoyancy shifts based on both the load shift *and* how much of the vessel is underwater. The center of buoyancy is the point through which the buoyant force seems to be pushing up.

Now, let's think about these additional factors.

The force that encourages the boat to heel or tip is called the "heeling moment." In a sailboat, this heeling is caused mainly by wind and waves. In a fishing boat, heeling is caused by wind, waves, *and* the distribution of the load.

The force produced by buoyancy that encourages the boat to right itself is called the "righting moment." When the righting moment counteracts the heeling moment, the boat is stable.

The "righting arm" is the term given to the distance between vertical lines drawn through the center of gravity and the center of buoyancy respectively (see Fig. 1).

A positive righting arm exists as the center of buoyancy moves from directly

under the center of gravity toward the heeling side of the vessel.

Fig. 1 shows the situation where the force causing the vessel to heel (the heeling moment) equals the buoyant force causing the vessel to want to right itself (the righting moment) and the vessel is stable.

In fact, as long as the righting moment is equal to or greater than the heeling moment, the boat will not capsize.

Angle of heel

Something interesting happens as the angle of heel increases. The volume of the vessel that is under water increases and the center of buoyancy changes — it basically moves toward the outside of the vessel.

This results in an increase in the length of the righting arm.

However, as the angle of heel increases even more, the vessel eventually reaches a maximum angle of heel where the righting moment can no longer counteract the heeling moment and the righting arm is as long as it can get.

The center of buoyancy then moves back toward the center of the boat, causing the righting arm to decrease in length. The boat becomes increasingly unstable until the center of buoyancy is directly below the center of gravity again, which means the righting arm is zero and the boat is very unstable because the heel is severe now.

As the center of buoyancy crosses over

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the vertical line through the center of gravity, the righting arm becomes negative and actually pushes in the direction of the heel. In other words, it assists in the capsizing of the vessel (see Fig. 2).

Broad beam vessels and those with greater freeboard have a longer righting arm and capsize less easily.

But vessels with equipment on deck — large reels, a superstructure, or a scallop rig for example — have a higher center of gravity.

In these vessels, the righting arm is shorter because the higher center of gravity moves more quickly through the arc of the angle of heel than a lower center of gravity. The result is that the righting moment can quickly become less than the heeling moment, and this results in instability.

Instability risk

Some of you reading this right now are particularly at risk for capsizing. This includes fishermen who have net reels, heavy winches, ice build-up on or above

deck, or a framework superstructure, and/or who haul heavy loads over the side or off-center rather than over the stern or on-center.

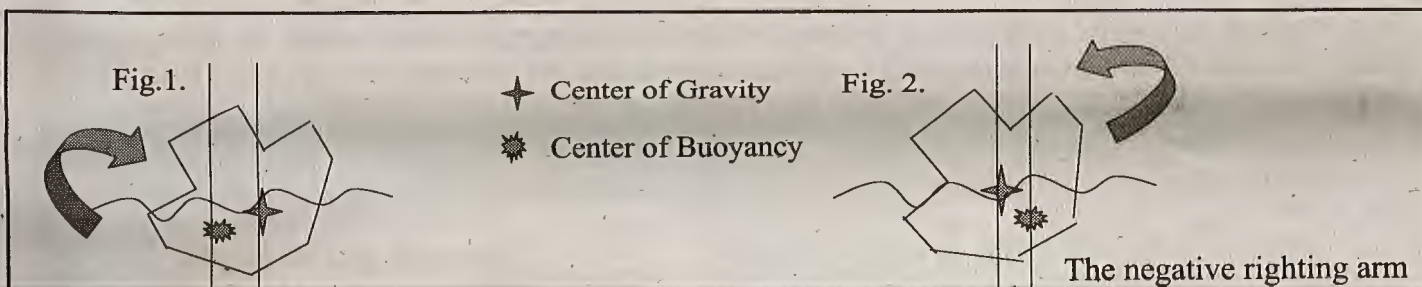
That's because the angle of heel can increase rapidly and unexpectedly with increased high or side load, a load hung-up on the bottom, a rogue wave, or a sudden wash of water onto the deck.

A short righting arm means less heeling angle over which the righting arm can act against the heel.

This discussion does not pertain to deep-keel boats because their center of gravity is below the center of buoyancy and as the boat heels, the center of gravity moves in the direction opposite the heel and the center of buoyancy can never get to the other side of the center of gravity. ■

FISH SAFE:

- Avoid conditions that raise the center of gravity such as adding equipment, ice, or superstructures to a vessel not designed for them.
- Use bins or water-tight compartments to keep the load from shifting in the hold.
- Haul along the centerline of the vessel rather than off-center to reduce heel.
- Maintain the integrity of the hull and through-hull fittings in order to minimize the amount of water entering the vessel. And
- Check that freeing ports are large



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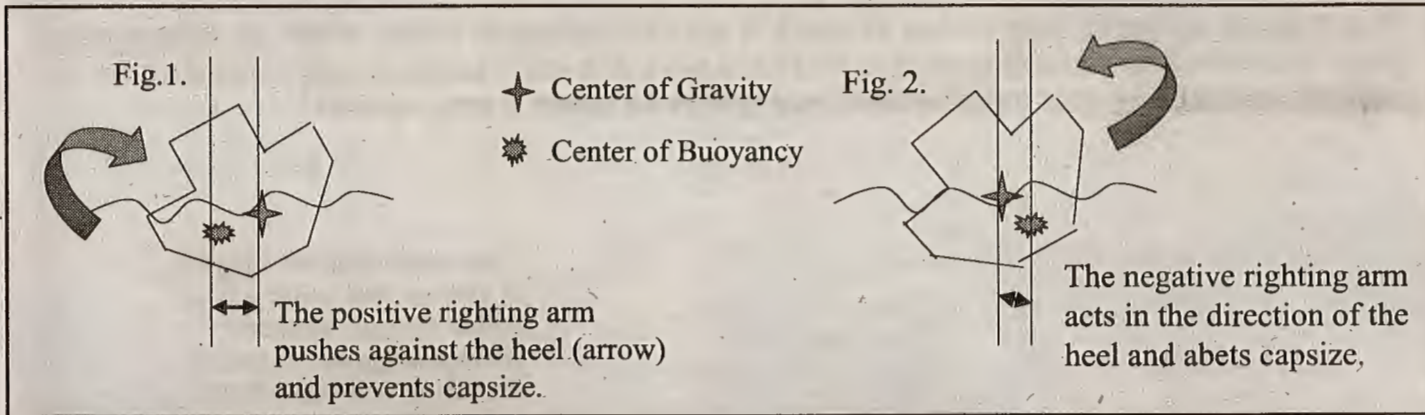
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