RYA – Navigation Handbook – Tim Bartlett – ISBN 978-0-901501-93-6 – extract pages 15,16,17

3 Direction

Direction is another of the fundamentals of navigation. It is so important that navigators seldom refer simply to 'direction' as such, but use a variety of technical terms such as course, heading, bearing, and track to refer to specific types of direction - such as the direction from one object to another, or the direction a boat is pointing.

Even so, we don't always need to express direction in particularly precise terms or in technical-sounding language. To say "the southbound tide starts a couple of hours before Low Water" for instance, may be a useful and accurate generalization. The more technical-sounding 'the tide starts flowing 180° at Low Water -2', on the other hand, would be wrong, because it implies a level of accuracy far greater than it actually achieves.

The formal definitions of north, south, east, and west are all based on the Earth's rotation (*Fig 7*):-

- East is the direction in which the Earth rotates.
- West is the opposite direction to east.
- North is the direction from a point on the Earth's surface towards the pole that would be on the left-hand side of an observer facing east.
- South is the opposite of north.

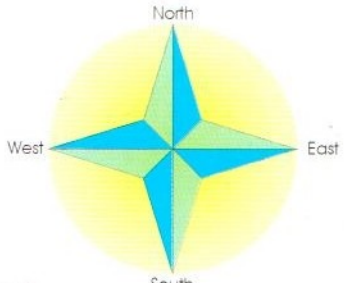

Fig 7

As most of us would have to think very long and hard to work out which way the Earth spins, these definitions are of purely academic interest. It is far more useful simply to remember the diagram (*Fig 7*) or to visualize a simple compass card.

Different kinds of direction

As navigators, we have to deal with many different kinds of direction. To distinguish between them, each one has a different name. Each of these technical terms has it own, specific meaning: course and heading for instance, are not interchangeable!

Bearing is the direction of one object from another.

Course is the direction the vessel is intended to be steered.

Heading is the direction in which the vessel is actually pointing at any given moment. It is very seldom exactly the same as the course.

Track Angle is the direction the vessel is actually moving over the surface of the Earth. The effects of wind and tide mean that it is not usually the same as the heading. In practice, the word angle is often omitted. Ground Track, Course Made Good (CMG) and Course over Ground (CoG) all mean the same thing.

Water Track is used by marine navigators to refer to the direction the vessel is moving through the water. It is sometimes called Wake Course.

Directions between these four **cardinal points** can be given names, too. Southeast, for instance, is mid-way between south and east, southwest is mid-way between south and west, and so on. Further sub-division produces eight quarter cardinal points, such as south southwest, westsouthswest. Even these can be sub-divided to produce 16 by-points, with names such as north by west - meaning 'a little bit west of north'.

Fig 8

Directions could be specified to a precision of just over five degrees by a further subdivision into half points. It's very difficult to steer a small boat any more accurately than this, so the points system survived in yachts and small commercial craft until the latter half of the twentieth century. Cardinal points, half cardinals, and quarter cardinals are still used for approximate directions (in weather forecasts, for instance) but for navigational purposes they have been almost entirely replaced by the three-figure notation.

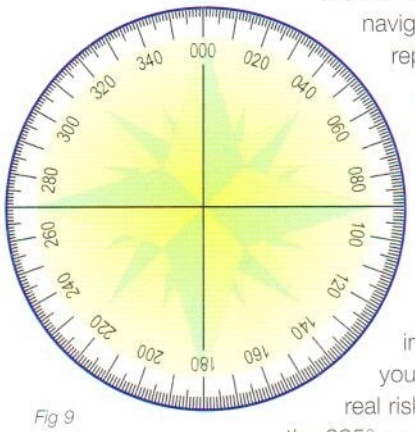

Fig 9

Three-figure notation is now virtually universal. Directions are referred to as angles, measured in degrees, counting clockwise from north, so east is 090°, southeast is 135°, and so on. (*Fig 9*).

Directions should always be written and spoken as three distinct figures. This isn't pure pedantry! Many small boat compasses are marked at ten degree intervals, with the final zeros left off to save space, so if you ask a helmsman to steer "thirty five" there is a very real risk that he will steer 350° (to the 35 mark) rather than the 035° you intended.

Measuring direction - in the real world

In order to measure direction, any boat should carry at least one compass. Most carry two or more. One is usually fixed to the boat itself, and is used to show the direction she is pointing, so it is called the **steering compass**. The other is a smaller, hand-held version used for measuring bearings, and known as a **hand-bearing compass**.

Sometimes, one compass can be used to do both jobs: a hand-bearing compass mounted in a suitable bracket, for instance, can be used as a steering compass, and is particularly suitable for cruising dinghies, small keelboats and RIBs. At the other extreme, many ships use a sighting arrangement called a pelorus or azimuth circle mounted on top of the main compass for taking bearings.

It's not unusual, though, for even quite small yachts to have several compasses. A yacht with tiller steering, for instance, may well have one steering compass on each side of the cockpit; a flybridge motor cruiser usually has one at each steering position. There may also be one at the chart table or over the skipper's berth, and another to control an autopilot.

Magnetic compasses

Although there are several alternatives available, the overwhelming majority of yachts and small motor boats use compasses that work by sensing the direction of the Earth's magnetic field. Essentially, the Earth behaves as though there is a gigantic bar magnet embedded in its core. Of course, there isn't really a magnet there, and it is still a matter of

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some conjecture exactly what is going on to produce the effect. Nevertheless, for centuries, navigators have been able to make use of the fact that a free-swinging, needle-shaped magnet will turn to point north south.

Small compasses, such as the ones used for back-packing and orienteering on land, still use a single magnetized needle as a north pointer. Most marine compasses, however, use several magnets, or a single ring-shaped magnet mounted on a circular card. The card is marked with a scale of degrees or compass points, and is suspended in a bowl filled with a mixture of water and alcohol. Of course, there are many variations on this theme: some compasses are designed to be looked at from above; some are designed to be seen edge-ways on, and there are even some that are intended to be viewed from underneath. The extent of the damping also varies: compasses intended for motor boats, in particular, are usually much more heavily-damped than those aimed at sailing boats, in order to cope with the rapid pitching motion.

An alternative kind of magnetic compass, known as a **flux gate**, has no moving parts, but uses electronics to sense the direction of the Earth's magnetic field. This has enormous advantages: a flux gate compass is compact, can easily be linked to other electronic equipment such as an autopilot or radar, and its output can be automatically processed to correct for errors. Because the sensor and display can be separate, it's even possible to reduce errors at source, by mounting the sensor wherever it will be least affected by stray magnetic fields. Apart from its dependence on electrical power, the big weakness of a flux gate compass is that it is very susceptible to tilt: for every degree that the sensor is tilted, it can easily produce two degrees of direction error. This problem can be overcome electronically, but most flux gate compasses also have quite sophisticated stabilising arrangements.

How a flux gate works

Like transformers, electric motors, and petrol engine ignition systems, a flux gate compass depends on the intimate relationship between electricity and magnetism, and in particular on the fact that if you pass an electric current through a coil of wire that has been wound around a suitable metal core, the core will become a magnet. Which end is the South Pole and which is the North Pole depends on the direction of the current flow, so if you pass an alternating current through the coil, the poles change ends every time the current reverses.

If you wrap another coil around this electromagnet, the opposite happens: every time the polarity of the magnet changes, it generates an electrical current in the outer coil.

In a flux gate there are two cores, side by side. Their inner (primary) coils are both made from a single length of wire, wound in one direction around one, but in the opposite direction round the other. The result is that when an alternating 'exciter' current is applied to them, they form a pair of perfectly matched magnets, pointing in opposite directions, and therefore cancelling each other out. In a magnetically 'clean' environment, this would mean that no current is ever generated in the outer (secondary) coil. When the cores are lined up with the Earth's magnetic field, however, this delicate balance is upset, producing pulses of electricity in the secondary winding. These pulses are most pronounced when the core is pointing north-south, and disappear altogether when it points east-west.

Practical flux gate compasses use several flux gates, arranged in a circle, and work by comparing the voltage created in the output windings of each one.