Taylor the Sailor

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There are some aspects of the life and writings of G I Taylor to appreciate which, one does not have to be mathematically gifted. And it is one of these aspects with which I am familiar, that I would like to describe here. This was his love of sailing, a passion I share, albeit with less understanding than his genius brought to this activity. Looking back late in life, he describes his career as a 'lifetime on the waves, mathematically and nautically', and bemoans the passing of the age of amateur scientists. Untenable as the amateur approach to science may appear to most in today's professional world, I cannot share more strongly his sentiments on this matter. Another common interest is flying, that he learned to do at the beginning of World War I, and about which he has many interesting anecdotes from those very early days of aeronautics. But the brief I have here is to deal with nautics.

Taylor records that his first attempt at navigation was to cross a pond in a tub. This led to a determination when he was at school to build a boat. As the era of readymade kits had not yet arrived, he had to both design, and build the boat, which he did in his bedroom fully aware that the boat was wider than the window. He had a carefully worked out plan of course, which was to remove the sash-window, put slings around the boat *turned on its side,* and to lower it with a rope that went round a pulley hung from a joist he had rigged to the roof. The only miscalculation the young Taylor had made was that the combined weight of himself and a cousin who were hanging on to the lower end of the rope when the boat was pushed out of the window, was somewhat less than the weight of the boat. He describes how the ensuing ascent of the pair as the boat came down, was stopped just in time by his brother seizing them, and adding his weight. Taylor calls it a good lesson in practical mechanics.

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Boats, sailing, cruising, navigation.

I was not surprised to read that his mother made the sails, as in those days sewing was almost as necessary a skill for women as

cooking. But one cannot but be impressed with the courage of a young lad who immediately after launching his home-built boat in the river Thames, sails down to the sea, sleeping very uncomfortably in the boat at night, and then takes it across the Estuary from Southend to Rochester! The varying combination of tide and wind and the density of traffic in this piece of water, make it a challenge of skill and courage to navigate it, even with the assistance of a motor as I can attest personally. But this clearly did not deter the teenager that Taylor must have been at the time, from doing this under sail alone, as indeed most craft had to do then.

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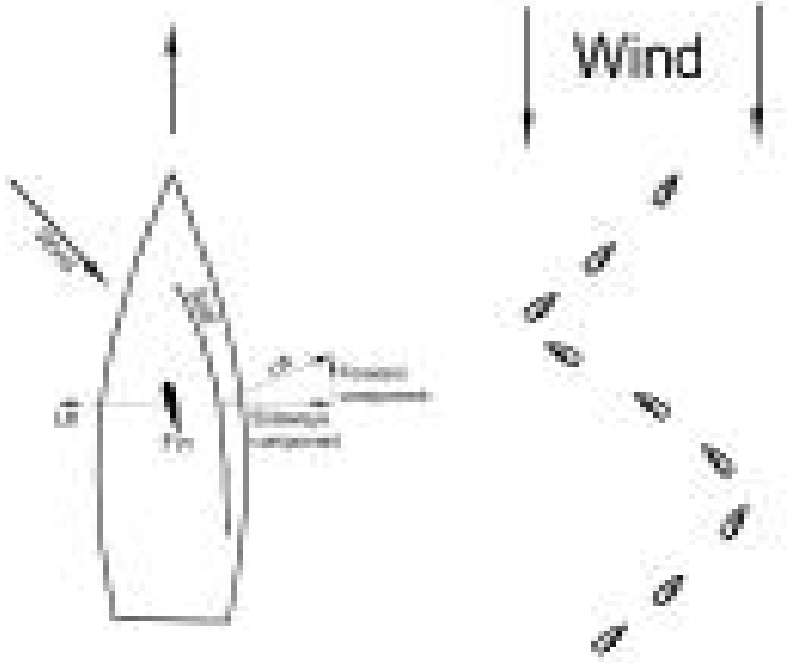
In fact, the difficulty and danger involved in such navigation under sail in a crowded area is illustrated by an incident on the return trip in which he ended up being involved, and that he has described with great humour. Tired of trying to make progress against the wind, (see *Box* 1), he managed to get a tow from one of the fifty or sixty barges all working their way upwind, and that soon after was involved in a triple collision. The verbal exchanges between the three skippers and their mates when the barges were interlocked and before one of them ultimately sank were apparently very educative. Taylor writes that he listened with admiration trying to remember some of the more imaginative phrases. He did not think he had, and I quote, “till many years later, when I was entering a lock in my forty eight foot yacht, the man who should have snubbed my progress failed to do so, and I thought I was going to ram the lock gates. Out they came. A lady watching from the lock wall was seen to pick up her Pekinese, stop up its ears, and carry it out of earshot.”

Collisions of boats whether with lock gates or each other, and procedures for their avoidance, belong to a world quite alien to landlubbers. Boats have no brakes. Motorboats with powerful engines can, like airplanes, reduce speed with reverse thrust, but sailboats are powerless, so to speak, to do so. To make matters worse, the ability to maneuver a sailboat is a strong function of the angle of the wind to the boat’s direction of travel. Add to it the current or tide which will carry along an ocean liner as easily

Box 1. Nautics and Aeronautics

Counterintuitive though it may seem, it is possible to use the energy in the wind to propel a sailboat to an upwind destination; the Chinese and the Arabs had done this for centuries before the Western world learned how. It is achieved by setting the sail not perpendicular to, but at a small angle to the wind, and using the generated aerodynamical force of *lift,* that acts at *right angles* to the fluid flow. This is as distinct from the force of *drag,* which is directed *along* the fluid flow, like that acting on a descending parachute.

By pointing the boat at an angle to the wind, and setting the sail at an even smaller angle, as in the diagram, a force will be generated which has a small component along the boat's axis. This can be used to move the boat forward, if and only if, the much larger sideways component can somehow be nullified. As discovered by the Chinese, this can be achieved by having a foil in the water moving at a small angle to the fluid flow. This will again produce *lift,* the magic force, in just the required direction to cancel the sideways push of the sail. By taking a zigzagging course, called tacking, one can thus reach any upwind destination.



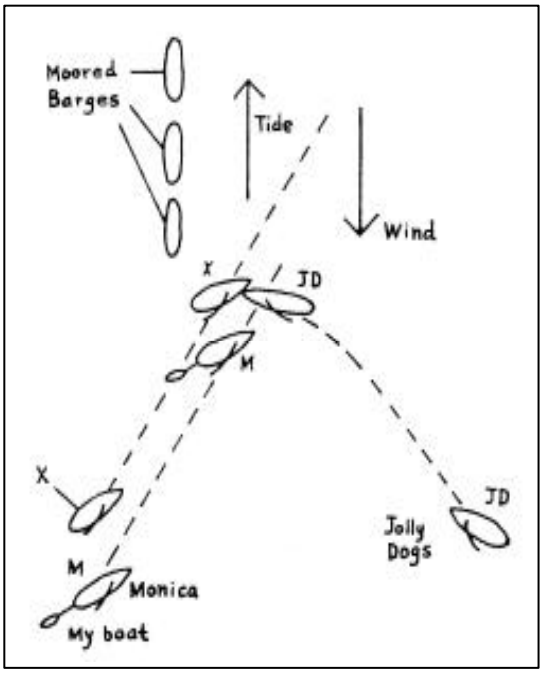
as a leaf, and one can begin to appreciate the risks involved and the skill required to stay afloat. To take account of all these factors, and that boats approach each other from all directions unlike vehicles on a road, the rules for collision avoidance assign priorities whose understanding presumes an expert knowledge of sailing.

The triple collision that he witnessed was also educative in another way, writes Taylor. As the three skippers and their mates gave different accounts of the cause of the accident, a pretty case was brewing for decision in the law courts. The counsel for the skipper of the barge that towed Taylor's boat and on which he was during the collision asked Taylor to describe what happened. He gave a consistent account and agreed to give evidence in court. The opposition apparently dropped their allegations when they learned that there was an independent witness, even though a schoolboy, not a bargee, who could accurately describe the collision. (See *Box* 2). Taylor concludes the account by noting that the amateur sailor's knowledge had proved valuable.

Box 2. The Rule of the Road at Sea

The diagram is a drawing by Taylor himself and the text below is his highly technical account of the collision as witnessed from the barge *Monica*.

"We were sailing close-hauled on the port tack (the wind on our left), normally, a boat on the port tack must give way to one on the starboard. But the rule of the road gives a close-hauled boat on the port tack the right of way over one on the starboard tack with the wind free. As we got near the anchored barges, *The Jolly Dogs*, a sailing barge on the starboard tack, came up on a collision course with a barge (X) just ahead of us on the port tack. *Jolly Dogs* could have held on and forced X and Monica to pass under her stern, but she then would have had to tack immediately after passing us to avoid the moored barges. Or she could have fallen off, thus losing her right of way, and passing astern of us. Unfortunately, she did not bear away till too late. The barges are labelled M, X, JD in the figure. In a short time there was a resounding crash as X and JD collided and Monica ran into them both. The collision positions are also shown."



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There were many more instances in his sailing career when it was proved valuable. One was an exciting voyage in 1921 when he set out from the Shetland islands for Norway with one friend in his 37 foot yawl which had no motor. As the sky was overcast he could get no star sights with his sextant, and in thick fog they approached the Skjaergaard, a line of offshore rocks and islets some miles from the mainland of Norway and extending hundreds of miles along it. After sailing 200 miles across the North Sea he saw "under the fog, white water washing on a rock about half a mile away". Just reading this sentence would send a chill down the spine of anyone who has been in a sailboat in a fog and not known where he was. And only such would admire the coolness and courage with which Taylor proceeded to safely reach his destination.

The chart apparently showed that the line of rocks ran exactly North and South with none of the really dangerous underwater rocks outside that line. Taylor turned and headed due north, just clear of the rocks but close enough to see one whenever the fog lifted a bit. And the distance between such sightings as read from his log[1] was noted and marked on a piece of tracing paper on which he had drawn a straight line. After a few hours when eight or nine such sightings had been made, of the many more that would have been made without the fog, he was able to find a match with the chart by moving the tracing paper up and down[2]. At that moment, the rock that was visible should, according to the chart, have a marker on it indicating the entrance to a narrow channel used by the local fishermen to get to the safe side. It did, and with the courage of his conviction he took this channel, and remarks in conclusion that "It was a small triumph, but now, with radio beacons and depth sounders, the amateur navigator perhaps needs less ingenuity". Dying in 1975, Taylor was spared the GPS age when the navigator does not even need to be literate. Taylor embarked on many more such voyages equipped only with the navigation aids available in those days. An intrepid and remarkable one in 1927 across the Arctic circle and back was awarded the Royal Cruising Club ChallengeCup.

[1] A log is a distance measuring device.

[2] This operation was a cross correlation.

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In connection with collisions, I said earlier that sailboats have no brakes to slow them down or hold them in one position. This is true in the open ocean, but in shallow water, as in harbours, ports and bays, there is available an approximation called an anchor. This is a device of iron weighing from a few to tens to hundreds of kilos, lowered on to the sea floor and attached by a long chain to a strong point on the boat or ship. Its shape is designed to dig into the ground and restrict the motion of the craft to a circle of radius roughly the chain length. If it works, then as wind and tide push the boat around, it will prevent collisions with other boats anchored at distances greater than the sum of the chain lengths. If it fails to hold, and *drags,* collisions can result with other boats or with the land if it is blown ashore. Worse, if the wind is offshore, and the craft unattended, it can be blown out to sea, and even lost.

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There are many designs of anchors, evolved over the centuries worldwide, but none of them is perfect; and it is a part of every sailboat skipper's life, including G I Taylor's, to have the anchor drag every once in a while, and cause a crisis or worse. In my own sailing days in the sixties, I lost an anchor and decided to replace it with one called a CQR, claimed to have holding properties far superior to the standard types. The part that dug in was shaped like a ploughshare and was hinged at a strange angle to the shank to which the chain attaches. Having spent all my money buying the boat, I could only afford a second hand CQR, but which I was proud of until I tried it. It was useless, and to my anger dragged every time. At a calmer moment it occurred to me that it was perhaps a cheap and poor copy, which suspicion was confirmed by comparison with some genuine CQRs. The crucial angle of the pivot pin was wrong, and so I had it cut and rewelded at the correct angle as there was no question of affording a new one. It now really worked and served me well at many stops on a long voyage halfway across the world. But why am I telling you *my* story?

If you go to GOOGLE and type in just CQR, you will find, as I did, over 6000 entries. They will tell you that it is an anchor with

Box 3. The Holding Power of Anchors

The figure shows on the left a traditional form of anchor with a stock that will lie on the ground and force one of the flukes to dig in as the chain is tensioned. The one on the right is the CQR type without a stock that will rotate itself to the correct angle, and retain it, without losing hold, even if the direction of pull is changed.

legendary holding power, is rated highest by Lloyds insurance company, is used by all sailors who know what is what, and the addresses of retailers who can sell you one at a competitive price. But if you want to know its origin, you will have to go to Volume IV of the *Scientific Papers of Sir Geoffrey Ingram Taylor, Order of Merit*, where on page 126 is an article entitled The Holding Power of Anchors [3]. This five-page paper is a masterpiece of the application of logic to the solution of a practical problem, and the invention of a device that must have saved countless craft and even lives over the seven decades since it was put on the market. (see *Box* 3). During its development, its stability in the ground was strikingly verified by Taylor dragging it round in a circle in a sandy beach. He writes that when he dug round the anchor at one stage to see how it was lying, he "*found that it had banked itself to do the turn, just like an aeroplane".* He concludes the article in characteristic style by saying "One thing is certain, however, the new anchor has no stock to foul the jib sheets when coming about, so that one continuing source of blasphemy will be removed".

The anchor had banked itself to do the turn, just like an aeroplane.

The Taylor I have described above is the one that I can relate to, as Americans say. The one that most scientists know of, and that other authors in this issue deal with, is the mathematical physicist who advanced and even dominated fluid mechanics and

aeronautics for several decades in the last century. I would like to conclude my own account of him with some remarks prompted, or should I say provoked, by the reaction of a colleague at the title of this article. " Really!" he asked in surprise, "Was Taylor *also* a sailor?" This fitted in with my view that many in India think of sailing, if they are forced to think of it at all, as a primitive and inferior form of locomotion used in our country only by fishermen too poor to afford a motor. There is also a feeling among some that people who build and handle boats are in some way of a lower class. As for the great prevalence of this activity in the west, that is seen from here as a pastime of the rich, their yachts being status symbols, and for the even richer, as lavish entertainment venues at exotic locations. So why would a serious academic like Taylor be messing around with sailboats?

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For me since childhood, sailing craft have been simply the most beautiful, noise-free, non polluting, non fossil-fuel depleting, eco-friendly and ultimately sustainable form of ocean transport, that made possible the discovery of continents, and later their linking for centuries. They are easy to get to love, hard to maintain and handle, and even harder to understand. They provide one of the purest forms of adventure, if you have the courage to take them to sea, and will make you realise very soon that nature is all-powerful and you are at its mercy. Crossing an ocean in a sailboat is an infinitely more worthwhile experience than sitting in a commercial airliner where you control nothing, see nothing and feel nothing. Your personal role in the fantastic physical achievement of traversing a sizable fraction of the earth in a fraction of a day is no more than that of baggage in the hold of the same weight. To sail across takes much longer of course, which is precisely what makes it memorable. On this matter I cannot resist another profound quote from Taylor. In his 1921 Wilbur Wright lecture, he pointed out that "every improvement in transport facilities makes it less worthwhile to travel on a globe of limited size because the place of arrival becomes more and more like the place of departure."

The last point I wish to make is that sailing craft are full of

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physics if only one has the wit to extract some. It was messing about with boats that led Lord Rayleigh to presage the role of a force, later called *lift* in aeronautics, a quarter century before that science was born. It was he and Froude messing about with boats, who recognised and recorded the phenomenon of the sideways lift produced in the water that makes possible upwind sailing. (see *Box* 1). Lanchester, the independent discoverer of circulation theory in aeronautics, wrote down in 1907, his still valid course theorem governing sailing craft, in strictly fluid dynamical terms. And as for Taylor himself, he describes the start of his famous career with "My earliest aerodynamic experiences were all connected with sails". I like to think that the above great scientists were all inspired by the aesthetic, intellectually challenging and soul uplifting aspects of the sailing craft they played around with.

Suggested Reading

[1] Sir Geoffrey Taylor, When Aeronautical Science was Young, *Journal of the Royal Aeronautical Society*, Vol. 70, p. 108, 1966.

[2] Sir Geoffrey Taylor, Amateur Scientists, *The Michigan Quarterly Review*, Lecture delivered at the University's Sesquicentennial Celebration.

[3] *The Scientific Papers of Sir Geoffrey Ingram Taylor*, *Mechanics of Fluids: Miscellaneous Papers*, Edited by G K Batchelor, Cambridge Univ. Press, Vol .IV, pp.126-130, 1971.

[4] G I Taylor, Across the Arctic Circle in Frolic, *Roy. Cruising Club. J.*, pp. 9-26, 1927.

[5] G I Taylor, Extracts from the log of Frolic, *Roy. Cruising Club J.*, pp.85-105, 1924.

[6] V Radhakrishnan, From square sails to wing sails: The physics of sailing craft, *Current Science*, Vol. 73, No. 6, pp. 503-516, 25 Sept. 1997.

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I am glad to have lived during a time when (aeroplanes) were simple enough for a reasonably intelligent amateur to appreciate them as mechanisms.

– G I Taylor