Fig.11

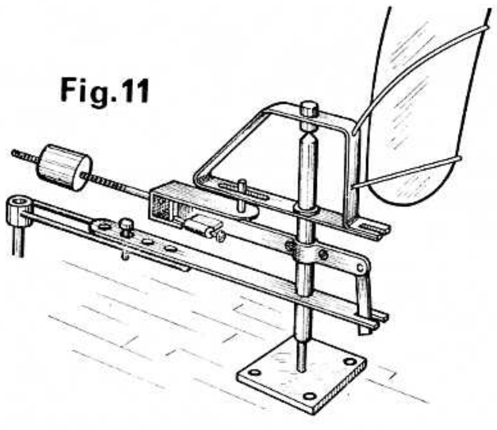
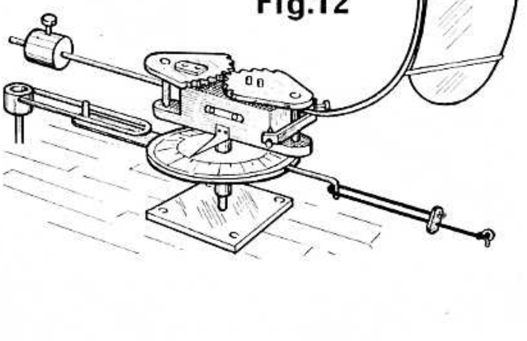


Fig. 12 shows a basic Ballantyne gear where the characteristic is the tacking motion being given by two equal sized gears set equidistant about the main vane pintle. This gear is readily balanced in both the 'fixed' and 'broken' conditions. Like the Lassel it gives positive lee helm when 'broken' and weather helm is entirely dependent on the angle of the heel of the boat when beating and the fact that both the feather and the counterweight are on the leeward side of the main pintle in this condition. Because there is no additional locking action of a toggle linkage it pays to have the feather and counterweight on the heavy side with this type of gear and have the mast position set for neutral helm on the beat. Should the mast be back from this position which would demand some weather helm there is a prospect that due to the speed of the boat through the water the pressure on the rudder may take control over the gear with the effect that the boat is driven up into irons when the boat becomes more upright and the gear is even less effective. This gear by its nature gives less trouble in failing to tack when the boat is put about.

The Fisher gear, Fig. 13, has a similar configuration to the Ballantyne except that the tack motion is obtained by a pin and slot linkage which is so proportioned that a degree of locking takes place in the 'broken' condition. This gear again is easily balanced for the 'fixed' and 'broken' condition. Because of the slight locking action it is suitable to apply a small amount of weather helm and since this is of some advantage, as will be discussed in the following section, the mast can be set back from the truly neutral position. Observation shows that at the present time there are probably more of this type of gear is use than any other, perhaps because many have been

Fig.12



produced commercially and it is also the easiest tacking gear to make for oneself.

The fourth type of self-tacking gear — the moving carriage — is illustrated in Fig. 14. It is the most complicated and probably has too many parts to make it a commercial proposition at a price that can be afforded, although it should not be beyond many model yachtsmen with some metal model-making experience.

The self-tack motion is controlled by lines from the main boom and therefore is very reliable. As long as there is wind in the mainsail it gives positive weather and lee helm. It is very easily balanced. These are its attractive points. In addition, insofar as guying is ever a reliable or unreliable manoeuvre, its action in this respect is as satisfactory as any. The tacking action is attained by a sun and planet motion of two gears which may be equal or have some other ratio which will be discussed in giving constructional details later.

What does Automatic Steering do for you ?

We have now covered general sail trimming and sailing practice, we have also given some brief idea of the various types of steering systems that have been used and in particular, various kinds of Vane gears. It now seems time to ask the question at the head of this section and answer it, particularly as so many people are not conscious of the right answer.

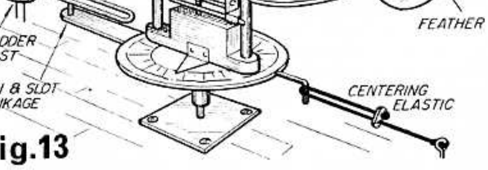


Fig.13

The answer so many would give is that it makes the boat go where you trim it, nominally from A to B. This may be the skipper's hope. The right answer, and one that must really be absorbed, to avoid frequent frustration, is that a yacht with sails and automatic steering correctly set on a straight course will sail at a constant angle to the wind. If the wind is constant in direction, then a fine course should be sailed and the boat should go just where you want it. It is seldom that we have true winds on our model yachting ponds and lakes and therefore the courses sailed will deviate according to the "flukes" in the wind. Very often these show a sufficiently constant pattern that use can be made of them and this all adds to the interest of model yacht racing, although such conditions usually favour the local skippers. Readers of Francis Chichester's single handed voyages when he has used vane steering will be aware that he records on more than one occasion waking after a "kip" to find he was on his way home again because of a 180 deg. wind shift, and that in mid Atlantic. Racing skippers are also not inexperienced in this phenomenon. We mention this because they supposedly know what they are doing. The less experienced think that their steering gear is not working properly and this is our reason for stressing just what automatic can do for you, and in a sense what it cannot.

Braine and self-tacking vane steering gears, besides steering on a defined course relative to the wind (which if the sails are correctly set should give optimum speed and therefore the fastest time from "A" to "B") are able to do three other things. (1) Guy. (2) Gybe; and (3) Tack by pole or hand without carrying out any adjustments. We see that four new terms have been mentioned and a little explanation would not be out of place. The first is the self-tacking vane. The Lassel, Ballantyne, Fisher and moving carriage gears briefly described in the last issue are all self-tacking. If you look at the steering compass (Fig. 5 in the February issue) you will see that when on a close port tack the vane feather makes an angle of 30 odd degrees to starboard relative to the axis of the boat. When on the starboard tack the feather requires to be at a similar angle, but on the port side. The non-self-tacking gear, Fig. 10, would require this movement of the feather to be carried out manually when the boat came to the bank and you wished to change it on to the opposite tack. Fig. 15 shows two boats in these positions just before coming to the bank and just after leaving. The self-tacking vane gear enables the feather to do this change of approximately 65 deg. automatically as the boat is "tacked" (turned on to the new or opposite tack) by pole or by hand. We thus see that we have not only defined (1) self-tacking gear but also tacking (4).

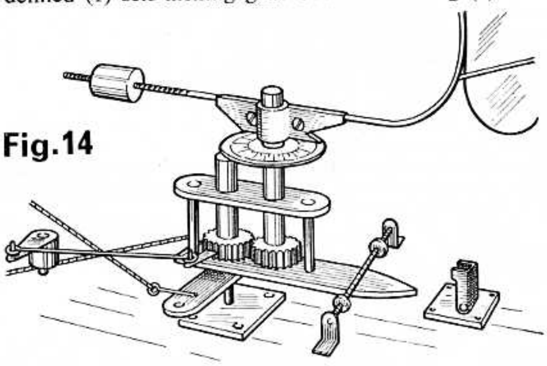


Fig.14

Now for (2) Guying. Guying is the ability to make the boat intentionally change tack when away from the side of the lake. Where this takes place not far from the side from which it has left it is called a "short guy" and when a long way away, frequently nearly the other side of the lake, it is a "long guy". How these are affected as well as those between will be dealt with later when we discuss the types of vane gears in more detail, but here the purpose of guying will be explained. Guying has two uses, the first is in racing where on the majority of waters it must be considered a vital necessity. Fig. 16 shows a fairly ideally proportioned lake for racing and the course taken by a boat with the wind in the direction shown. From this it will be seen that if a plain tack was made from position "X", the course followed would be the dotted one to "Y" and then after changing tack once again to "Z", whereas by quickly setting a short guy at "X" the course would be that of the solid line to "W" over the finishing line after a relatively few yards. If the course had brought the boat to "X1" then a longer guy to "W1" would still be better than to "Y1" and "Z1". The other use of the guy is when sailing alone on a largish water and the wind is fairly straight down the length of it,

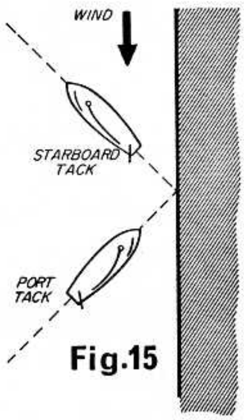


Fig.15

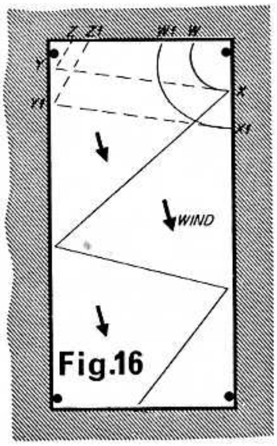


Fig.16

effective long guys save a lot of walking or running round the water and add considerably to the enjoyment. The long guy also comes to its own in racing where the water is wide such as the Round Pond, Kensington Gardens, London. It is recognised here that when the wind "is down the pond" guying is the quicker way to get to the finishing line than tacking as would be done on a narrower water.

Now we come to the third term, Gybing. It would be more correct to say the facility that the gear gives is the return or correcting gybe. These conditions arise with the wind behind the boat, i.e., on the run, with the main boom well out over the side of the boat. If, due to over-steering or a fluke puff of wind, the boom and main sail are blown to the opposite side, it is said to have gybed. Unless the wind was previously dead behind the boat there will be a deviation of course as shown in Fig. 17. What we want our automatic steering gear to do is to turn the boat back again to course and get the sail back on to its proper side and driving again, i.e., it is a return or correcting gybe. This then is what our gear can do for us, as we shall see when describing the gears in more detail.

How the Vane Steering Gear Works

As was said in the earlier brief section on the different types of vane gears, the balanced non-self-tacking gear can be used for all "plain" courses. Because of the simplicity of this gear we will use it to describe how the gear works on all straightforward courses. Fig. 18a and b show a side view (in section) and a plan view of the gear simply shown earlier as Fig. 10. Now is the time to describe the parts in more detail. (a) is the rudder post which is surmounted by a simple quadrant (b) with a slotted "tail" and a forward projection used for a balancing weight, a matter which will be discussed under

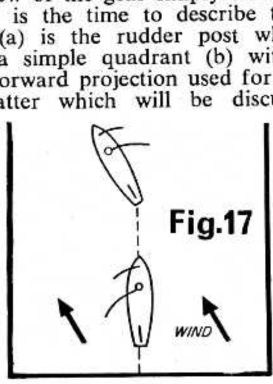


Fig.17

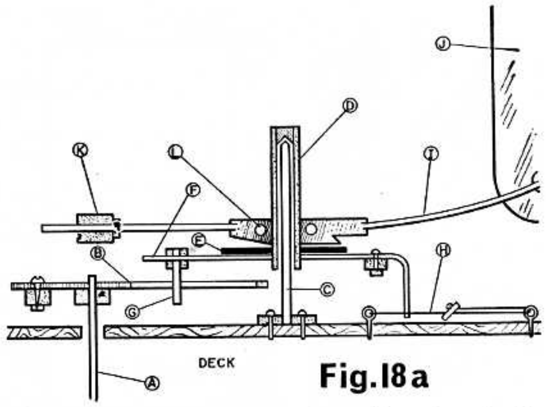


Fig.18a

balance later on. Note that the tail projects backwards almost to the pintle (c) on which the vane swings. (d) is a tube with a point bearing in the top and mounting the scale (e). A forward arm (f) carries the pin (g) which engages in the slot of the quadrant tail. It is useful to be able to adjust the pin position and this accounts for the three holes shown. A short arm projects aft. The small downward bent portion has a small hole through which the light centring elastic (h) passes. Finally we have the vane arm (i) carrying the feather (j) at one end and the counterbalance weight (k) at the other. This arm fits over

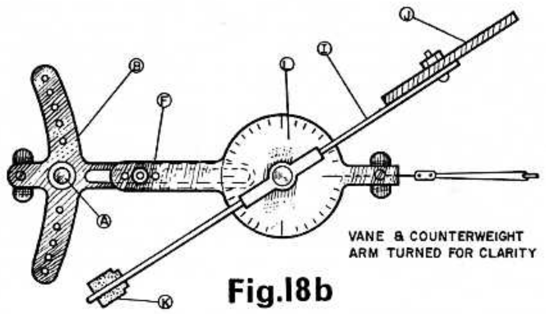


Fig.18b

the tube (d) on which it can be turned either clockwise or anticlockwise through a full 360 deg. Screws (l) enable it to be made friction tight so that it can be turned by hand to a chosen scale position; it will be too stiff for the wind on the feather to do so.

The simple gear described by Mr. Draper in the November 1964 *M.M.* shows how the pin and slot motion can be replaced by gears which give a constant angular motion between the vane and rudder movement. The restriction of the tooth by tooth adjustment can be overcome by the friction drive of the vane arm as described above.

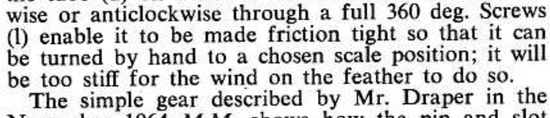


Fig.19

Fig. 19 enables us to take the first simple step in understanding the vane action. It shows a boat with sails and vane set approximately for a close beat on the starboard tack. The vane is shown "flying" like a weathercock in the wind; this, as we shall see later, is not strictly accurate, but for the first step it facilitates the simple explanation. Consider that the boat is sailing happily on the course shown, sails full and drawing and the rudder neutral. A wind shift comes along so that the wind now comes from W1, shown dotted. It now strikes the starboard face of the feather which will turn clockwise. Through the pin and slot—or gear—motion the rudder will turn anticlockwise and the boat be steered so that it resumes a course at the original angle to the wind. Note that this is what we said an automatic gear does. As the boat turns from its original direction to its new one the wind pressure on the vane eases until the feather is once again flying in the wind and we have equilibrium. If the wind had moved the other way the wind would have struck the feather on the port side and the movements would have been, vane: anticlockwise and rudder: clockwise. The course would again have been corrected to the same angle to the new wind. If now it was not the wind that shifted but rather that the boat fell away from the wind, the gear will try to steer the boat back on course relative to the wind. This condition arises when the sails are not set at the optimum angle for the course being dictated by the vane angle setting. Similarly if the sails are too tightly set the boat sails up into the wind on the sails and the vane tries to hold it off, not really sailing at all. This emphasises that to sail well the sail and vane angles must be in harmony. Now turn to the sailing compass, Fig 5, and apply the above wind of course shifts and see that each time the vane always moves the rudder the right way to correct the course.

Before considering the self-tacking gear and the question of balance, we must consider WINDS, real and apparent.

Winds, Real and Apparent

The real or true wind is that indicated by a weather cock in a high unobstructed position. To appreciate more readily an apparent wind when we come to it, it is worth pointing out that the true wind is observed from a stationary point. It will be clear from this that when you are at the pond side trimming your boat it is the true wind you feel in your face or on your side or behind you. The feather of your vane gear, which flies like a weathercock, is on a moving point when the boat is sailing and operates to the apparent wind. To appreciate the difference between true and apparent winds carry out the following experiment. Stand in an open space, holding a small flag, and turn so that the wind is coming directly to one's side. The flag will flutter directly across from, say, left to right. Now walk briskly or run forward. The flag now feels the apparent wind and no longer flies directly across but as if the wind is coming from somewhere in front. This is a product of your motion and that of the true wind. The effect on the feather of a boat in motion is just the same. The effect can be resolved by "triangles of forces", in which, if the wind speed is reversed and plotted at the appropriate angle relative to the boat speed plotted in its actual direction, the line joining the outer ends of these lines will be in the direction of the apparent wind and of a length proportional to its strength.

Fig. 20 illustrates the apparent winds for a number of starboard courses. The wind has been taken as 10 m.p.h. The boat speeds have been varied according to the probable speeds on the various courses, 1½ m.p.h. on a close beat, 2 m.p.h. on a close reach, and 3 m.p.h. on the broad reach and running courses. Strictly speaking boat speeds should be in knots, that is nautical m.p.h., but it is certain you will appreciate working in m.p.h. with which the majority of us are much more familar. One thing to observe particularly about the direction of all the apparent winds is that they appear to come from closer to the direction the boat is sailing than the true wind you feel when trimming the boat from a stationary position at the pond side. An allowance based on experience must be made for this.

No doubt you will wish to draw for yourself more apparent winds in other directions and with different wind and boat speeds. Two points must be made; (1) as wind speeds rise you have to reduce sail so boat speeds do not go up on that account, and (2) the maximum speed a boat hull can be driven through the water in a non-planing condition is related to its water line length. The formula that enables this to be calculated is $V = X\sqrt{L}$ where V is the velocity (speed) in knots, L is water line length in feet and X is a factor. It is an empirical formula, that is one based on observed performances and the factor X varies for different hull shapes. That for typical racing yachts is 1.6. Applying this to model yachts it gives a maximum speed of 3 m.p.h. for 36 in. class boats with a 35 in. waterline, 3.5 m.p.h. for Marbleheads with a 50 in. waterline (which nowadays is often met) and 3.75 m.p.h. for a 10 Rater with a 56 in. waterline. From this you will realise that your model seldom goes as fast as you think it does.

Other Factors in Trimming the Feather

Having seen how one must estimate what the apparent wind will be in trimming the feather, attention must be drawn to two other factors. The first is perfectly straightforward, the second, in a degree, controversial. In dealing with plain sailing it was pointed out that with a balanced boat on beating trims no helm was needed but, as the course being sailed moves from a broad reach to a run, the mainsail shades the jib from the wind and this unbalances the forces on the sail plan and, without some weather helm, the boat would turn towards the wind. Now this helm is to be given by the vane gear. Anyone who has steered a full-size craft, even a dinghy, knows that some force has to be used to hold the rudder against the slipstream of the water in which it is moving. In the case of our model yacht the water pressure is transmitted back as a force to the feather, and to hold the rudder at an angle against the water flow requires an equal and opposite force to be applied by the feather. One thing that must be appreciated is that a vane feather flying freely in the wind, i.e., the wind is flowing equally on each side of it, can exert no force at all. For the feather to be able to exert a force on the rudder it must be set at an angle to the wind so that the wind is "hitting" one side of it—suction will be created on the other and these two effects will enable the feather to transmit a force to hold the rudder against the water.

The interesting—and convenient—thing about the angular movement which must be applied to the feather to create these conditions is that it is towards the position of the true wind when you, and the boat, are stationary at the pondside in the process of trimming. This is a bit of luck, but remember it only applies on courses from a broad reach to a run without a spinnaker. Now for the factor which is a little more controversial, and this applies as much on beating courses as on the run. So far in discussing boat sailing we have talked of and assumed that we were dealing with a balanced hull with a sail plan placed over it so that on beating trims no helm was needed. This in turn means that the rudder can be wobbling slightly in the slip stream and that the feather is doing the same on deck. This fluttering is undesirable and it almost certainly means that the boat has to deviate more from the wind before the helm can take effective control, than if the feather and rudder were "biting" ever so slightly at the wind and water while on the desired course. This same condition can be experienced on full sized craft, though seldom are they so well balanced, and skippers will tell you that the boat with the wobbly rudder lacks drive and a degree of control.

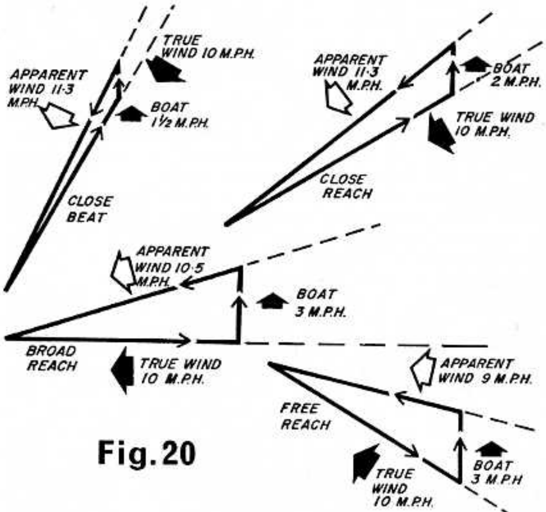


Fig. 20

It is not unusual therefore for the sail plan, of even well balanced boats by design, to be moved backwards a small amount—increasing the rake of the mast may be sufficient. The effect of this is to give the boat a slight (and it must only be slight) tendency to head into the wind on the sails alone. This requires offsetting by the slightest amount of weather helm. Here again it is a coincidence that the feather movement to give this is towards the true wind position, and this of course applies on all points of sailing. It is sufficient to terminate this discussion by saying start your vane trims by letting the feather fly to the true wind when trimming with the rudder neutral (central), and the deviations from this that you must allow (for the factors above mentioned) will come to you quickly with experience. Nevertheless it is nice to know what you are doing and why you are doing it.

★ ★ ★

BALANCE has so far been quoted and defined as it applies to a hull. We must now consider it in respect of steering gears and it is convenient to do so relative to the simple gear we have so far used as our illustration. How it affects the more complicated gears will be covered as they are dealt with. Two things must be clear to all who have read so far: (1) that there is not a great deal of power in a vane gear and (2) that it is intended to work on wind direction relative to the boat's course and not other forces.

Item 1 should be taken care of by using an adequate size gear with an appropriate size and shape of rudder and ensuring that all parts move very freely. The latter point cannot be emphasised too much. A little "slap" or backlash is much more to be preferred than the smallest amount of binding or stiffness. This applies to the rudder as much as it does to the gear—it is all part of the steering mechanism of the boat.

Item 2 is taken care of by balancing.

Balancing the steering mechanism is therefore the exercise of removing as far as possible other forces which would detract from the efficient operation of the steering.

Turn once again to Fig. 18. In your mind take the vane off its pintle, just leaving the rudder and its slotted arm in position. Still in your mind place the boat in a bath of water. Heel it to port or starboard. If the rudder is made of wood it will try to float upwards, while the slotted arm on the top of the rudder post will try to force it downwards. The forward projecting arm is there to enable small weights (a brass nut and bolt and some washers) to be fitted to "balance" the rudder and arm so that when the boat heels when it is sailing, unwanted helm is not going to be applied. If your rudder is made of metal, change it for a wooden one as the weight necessary to balance it as described above will add too much unwanted weight to your boat. These ideas are best thought about in your mind before applying them to your own boat. The next step is to turn the rudder to one side so that just the tube and scale of the vane itself can be put on the pintle and they will swing clear of the tail, i.e., we have taken off the feather and counterbalance arm. Heel the boat and the pin arm will almost certainly rotate downwards. This piece of the mechanism should also be balanced by small weights on the opposite side. When this is done the rudder can be centred and the pin engaged in the slot. The combined mechanism will now be unaffected by heeling. These parts, it will be realised, have a relatively small rotational movement when in action, but their position relative to the axis of the boat when heeling (of which a boat does a great deal when sailing), is very critical from the point of giving false helm, which can so easily be in opposition to the small forces for which we are looking to the feather.

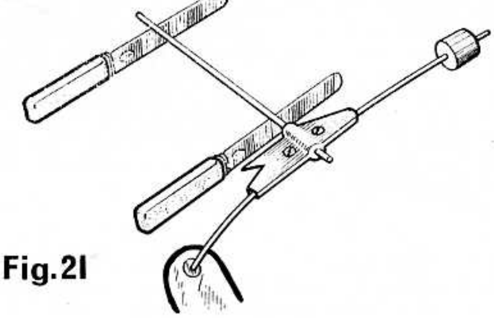


Fig.21

The feather and counterweight assembly on the other hand can be turned to any angle through 360 deg. For this reason they must be balanced on their own. To do this attach them temporarily to a rod of the same diameter as the tube and rest the assembly on knife edges as shown in Fig. 21. The counterweight should preferably be about the same weight as the feather. This can most easily be tested on a letter balance. The counterweight is then adjusted with the feather properly set till the assembly will stay in any position it is put. It is then balanced. You will note the comment " with the feather properly set". Some feather mountings automatically set the position (angle to the vertical when on the boat) while on others you have to guess the set, usually the leading edge vertical. It will be apparent from the above that if the feather setting is moved the balance will be destroyed.

The feather assembly can now be put on the tube and the whole gear is balanced, i.e., the boat can heel when it is sailing and the gear will have no gravitational or flotation vices. Mention must finally be made of the centring elastic and then you fellows with a simple gear like that used in the description can go sailing. The centring line, like a feather flying neutral in the wind, exerts no force while it is central, it only does so when the assembly to which it is attached moves it off centre. Since it is usually the wind on the feather that usually does this and we have already said we are short of power you might ask why put an elastic to oppose it? A fair question and a fair reply would be that if we could have no friction at all in our gear then the slightest movement of the boat in the water would align the rudder to neutral, and the gear on deck, when the light airs leave the boat. But because there is always some friction, sufficient elastic centring effort should be available to centralise the gear under these conditions. To meet this it is sufficient to use the lightest of shirring elastic.

The centring line is also useful when the wind is particularly "fluky" and a free gear would be spinning a boat all over the place following the flukes. To be able to alter the tension of the centring line under these conditions and improve apparent performance under such difficult conditions is well worth while. You must realise that it is being achieved by partly neutralising the normal efficacy of the steering.

Self Tacking Gears

Having mastered the non-self-tacking gear, attention can now be directed to the self-tacking vane gears. It has already been explained that the self-tacking gear primarily does two things (a) to change the vane angle from one tack to the other when the boat is put about without the gear being touched (see Fig. 15). This is most important since it is the racing rule which permits change of tack by "Poling" which stipulates that the lee bow before the tack and the lee stern after the tack are the only parts permitted to be touched if the boat is to be tacked without losing way and not stopped for a retrim. (b) Guying. This was described and illustrated in Fig. 16. You can guy with a non-self-tacking gear of the type used to introduce vane gears, but the action of the boat will be so violent, unless there is practically no wind, that it will almost turn a full semicircle in its own length. This is useful sometimes, but not often.

Two terms of jargon have already been used with respect to the self-tacking gear, namely "fixed" and "broken", and now is the time to define them. A self-tacking gear is spoken of as "fixed" when it is adjusted to be working as a non-self-tacking gear, that is, it is moved by hand to any working point of the scale to determine the course to be sailed and it remains "fixed" at that setting. A self-tacking gear is said to be "broken" when the self-tacking action is in operation and it will move from the setting required for one tack to that required by the other automatically as the hull of the boat is turned through the eye of the wind. Since this facility is only used on close beats the adjustment provided is invariably only over the angle to do this, i.e., not more than 40 deg. each side of centre. The angle required on each side of the centre line should be the same for a well built hull (symmetrical) even if the hull form is badly balanced. It is usual nevertheless to have independent adjustment for the angles of the self-tacking on either side as we shall see in examining designs. Since hull designs only show the details of one side, lack of symmetry in the hull performance can only be in the building unless the sails and deck gear are one-sided, so if you find you need different vane angles for the two close beating tacks look to your standing rigging as described at the beginning of the series. You can do nothing to your hull but put up with it, or scrap it, if it has been built one-sided.

Self Tacking Gear Designs

The designs will be examined in the order in which they were introduced in the earlier articles, so first we will deal with the "Lassel" gear. This gear was quoted as historically one of the earliest self-tacking gears that became at all popular. Today one seldom sees a Lassel type gear in this country and this is probably because its disadvantages outweigh its advantages and also that the design of self-tacking vane gears has in any case progressed. In the study of vane gears it offers some advantages for the purpose of discussion even if they point to mainly what not to do. The Lassel gear is included here for these reasons. Fig. 22 a, b, and c show an elevation in partial section, a plan, and a straight line diagram for studying its "balance" as we shall see.

You will immediately recognise the fundamental parts; the rudder post with quadrant and "tail", the main pintle, the central vane tube with its scale and forward projection carrying the pin for engaging in the slot of the quadrant tail. The feather and its counterweight are also easily recognised. You will see that the counterweight is supported on point bearings while the feather is supported on a pintle on the main tube or stem and is connected to the counterweight assembly by a pin and slot motion. With the locking catch in the "UP" position the feather and counterweight assemblies are locked in line on the carriage that carries the counterweight assembly. This carriage is friction mounted on the main tube or stem and therefore the locked assemblies can be turned to any scale position just as in a non-self-tacking vane gear. This is known as the "fixed" condition. To balance the gear it can be treated just as the non-self-tacking gear previously described starting with the rudder and quadrant, then the central tube, scale and pin arm, with the feather and counterweight assemblies together on a rod before fitting to the central tube.

With the feather and counterweight assemblies in a fore and aft setting, the feather being aft, move the locking catch to the downward position into a slot

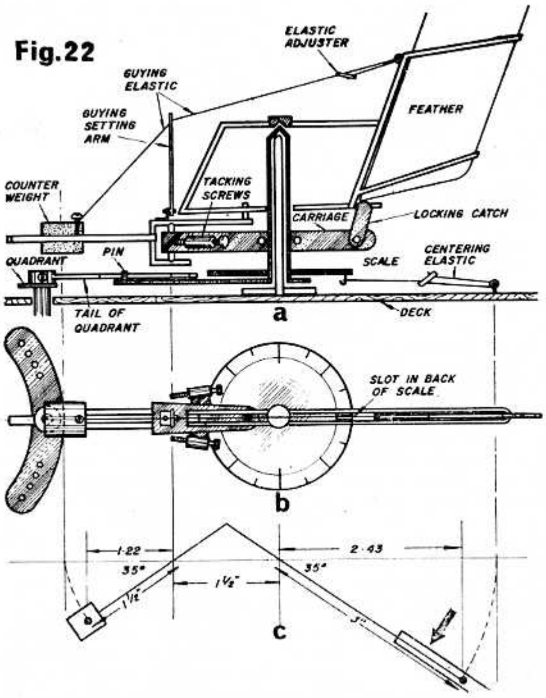


Fig.22

in the back of the scale. This locks the carriage in the same fore and aft setting every time you set the gear in this way and is clearly an advantage. The action of switching the locking catch from the top position to the lower one has released the lock between the feather and counterweight assemblies which are now free to move from one side to the other, but note both are on one side, either the port or starboard, at one time. If you heel the boat to starboard as if the wind was blowing over the port side both the counterweight and the feather fall to the starboard side, which if you look back at Fig. 15 is where the feather is required to be. Heeling the boat to port, the counterweight and feather fall over to the port side, which looking at Fig. 15 is where the feather is required to be on the starboard tack. The self-tacking gear is said to be "broken" in this condition. With the Lassel type gear the feather assembly pivots on the central tube and therefore the scale can be used to see the angle the feather moves to on the two tacks in both the fixed and broken conditions—another advantage of the Lassel design. The angle can be adjusted independently for the two tacks by the tack adjusting screws which as you will see act as stops on to the frame of the counterweight assembly. Frequently in this type of gear the mounting of the adjusting screws was made to move backwards and forwards as a whole so adjusting the port and starboard tacks simultaneously once any slight differences in the requirements between the two tacks have been established.

THE Lassel type gear has, as mentioned, among its other features a simultaneous adjustment of port and starboard tacks, and Fig. 23 shows this in detail. Note that with this gear the carriage is locked in the fore and aft position when the gear is "broken".

We can now look at the question of balance in the

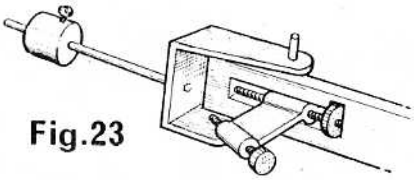


Fig.23

broken condition and for this Fig. 24 will be useful. This figure shows the ideal condition in a single line form where the weight or mass of the feather is the same as that of its counterweight and they have both moved through an equal angle of say 35 deg. Their leverages are therefore equal and the gear is balanced, in that there is no unbalance of gravitational forces to give the rudder a bias. The forces or moments are each equal to the radial distance to the centre of gravity of the mass times cosine 35 times the mass. Since we have made the masses the same and the radii then all is well. Now look at Fig. 22c which is the configuration applying to the Lassel gear in the "broken" condition. Here if the masses of the feather and counterweight are the same and say the radius of the feather is 3 in., then for balance in the fixed condition the counterweight would also be on a radius of 3 in. This radius is however made up of two parts, say $1\frac{1}{2}$ in. each, which come into play when the gear is broken. The moments of the feather and counterweight are then mass of feather times 3 (inches) times cosine 35 while that of the counterweight is mass of counterweight (the same as the feather) times ($1\frac{1}{2}$ times cosine 35, plus $1\frac{1}{2}$). Cosine 35 is .813 so that we see the feather moment is 2.43M while that of the counterweight is 2.72M giving a considerable bias in favour of the counterweight which in turn will give weather helm, i.e., if the gear is balanced in the fixed condition it will tend to steer it off the wind in the broken condition. To those not so mathematically minded, Fig. 22c is drawn to scale —or you can draw it out to a larger scale—in which it can be seen that the line of action of the counterweight is farther from the central pintle and will therefore exert the greater force. This inability to balance the Lassel type gear in the two conditions, without adjusting it, is undoubtedly its greatest fault.

Looking at Fig. 22c again you will see an arrow pointing at the face of the feather. This is the face of the feather that will "feel" the wind if the boat, when sailing, tends to fall off the wind. Wind on this side of the feather gives LEE helm to steer the boat up into the wind and we say it gives this positively because the pressure on the pin and slot movement to the counterweight is locking them harder together.

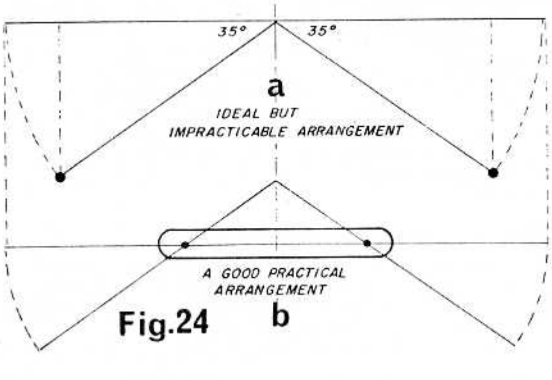


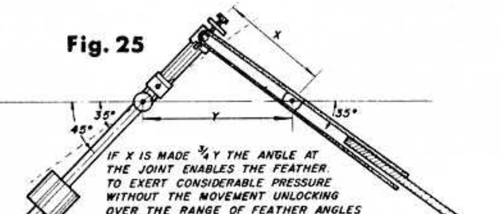
Fig.24

If the wind strikes the other side of the feather due to the boat or wind heading, then the force on the feather will try to unlock the pin in the slot. The power of the gear to give weather helm is therefore not so great. This characteristic is minimised by two devices in the design. The first is shown in Fig. 25 which shows how the pin and slot motion is proportioned so that the tendency to unlock under pressure is minimised. This requires a slightly greater angle of movement of the counterweight which in the case of the Lassel type gear helps towards balance. The other device is the Guying elastic. This is terminated so that the pull in the non-guying setting goes over the dead centre and therefore helps to hold the pin against the end of the slot. This must not be overdone or the gear will fail to flop over when the boat is tacked. With the guy setting arm in the vertical (neutral) position the force applied to the motion tends to hold the gear to whichever tack it is on.

Now to Explain Guying

If the guy setting arm is pushed over to a horizontal position, say on the starboard side, the elastic will pull the feather and counterweight arms on to the starboard side. If the counterweight is manually moved over to the port side (the feather will automatically follow due to the pin and slot linkage) it will be noticed that the elastic is not now taken over a dead centre and on releasing the hold on the counterweight both arms spring back to the starboard side. To sail the boat now with this setting of the guy it will be found that the performance on the port tack is quite normal because the arms are held over to the starboard side as required. When the boat on coming to the bank is turned, new forces affect the gear; firstly the heel of the boat on the new tack gives a gravitational force to the counterweight to swing it to the port side, aided by the weight of the feather which in turn also has the wind on it now to blow it over to the port side, and opposing these movements is the guying elastic trying to spring both arms back to starboard as was described a little earlier. What in fact happens depends on the strength (1) of the elastic, (2) that of the wind, which heels the boat, and the angle to the wind to which the boat is turned. If the elastic is very strong it will hold the feather and counterweight arms against the other forces and the wind on the feather will cause so much helm to be given that the boat will quickly spin round back on to the port tack—hardly a guy at all, but one that must be classed as a short guy. If the elastic is weak then the gravitational forces created by the heel of the boat and the wind pressure on the feather will be such that the boat will sail to the other side of the pond on the starboard tack unless there is a complete lull in the wind when all the heel comes off the boat and this boat motion

Fig. 25



coupled with the elastic tension will swing the arms over to starboard and the next little breeze will quickly bring the boat round on to the port tack. This would be a long guy. A little thought will show that the restoring power of the elastic guy can also be varied by the position of the guy setting arm between the horizontal and vertical positions. The ideal adjustment is such that with the arm horizontal a shortish guy is executed when the boat is only turned just through the eye of the wind. It will then be found that by turning it further you will execute a longer guy, and that movement of the arm nearer to the vertical will continue to lengthen the guy. Finally it must be emphasised that long guys largely depend on a lull in the wind or sailing into a calmer patch. The latter can very often be operated with great consistency.

Guying has been gone into in some detail here because this same form of guy is common also to the next two gears to be described.

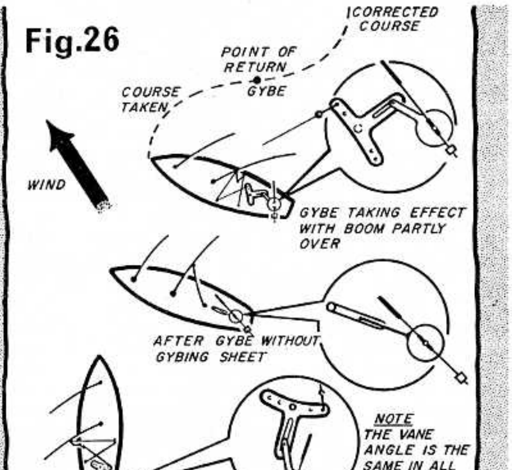
SINCE the opportunity was taken to discuss guying at some length before describing the design principles of the second type of self-tacking gear, so will we digress to *Gybing,* again for the reason that one arrangement in the author's opinion can be applied fairly universally.

The vane mechanism itself is ineffective to correct a gybe for two reasons. The first is that it has least power on a running course. Reference back to the article on apparent winds shows that the force of the apparent wind is least on a full run, because it is that of the true wind speed less the boat speed. The second and more important is that the feather is in one of two ineffective positions to generate power to effect a gybe, (a) if a spinnaker is being carried the feather will be very close to the full forward position and there is not likely to be sufficient deviation from course to generate any side pressure on the feather. The second case (b) is perhaps more interesting. It is that when running without a spinnaker, as explained earlier on sail trimming, when the wind comes from abaft the beam the mainsail "shades" the jib and it is necessary to apply weather helm to balance the boat. Again as was explained earlier, to generate a force to operate the rudder against the flow of the water it is necessary to offset the feather to present a face to the apparent wind. Fig. 26a shows the settings of the sails and feather relative to the wind on such a running course before a gybe. Fig. 26b shows the situation when the gybe has taken place in which it is immediately seen that the offset to the feather required on the original course and tack now weakens the power of the feather and leaves the boat sailing nearer a reach on the new tack. In fact for the vane to be at all effective a vane motion similar to the self-tack on the beat would be required, in which with the change of tack there is an appreciable change of the angle of the feather. No doubt this could be engineered but would be a further complication to the gear when there is a much simpler and neater solution which, having shown in what respects the vane fails, we shall now describe.

The method recommended by the author and seen to be applied by the majority of racing skippers is really using the gybing "half" of the Braine steering gear and not using the steering "half". It will have been noted on the various figures of gears so far illustrated that a quadrant on the rudder post has been shown. Fig. 27 shows in plan view the features of the running sheets with the gybing condition. The running sheet is double from the bowsie on the boom to the two sheet hooks. The form the sheet hook takes is illustrated in the inset to the diagram and this shape is used to facilitate changing its position quickly and at the same time give a secure hold to the horizontal working pull. Having the sheet double all the way from the bowsie avoids knots negotiating the metal ring on the boom at the point the sheets leave the boom, and sticking just when you are in a hurry. The two halves of the sheet must both be the same length.

On the deck forward of the quadrant is the sheet anchor plate—or plates. The alternatives are shown in Fig. 27. A little geometry comes into the placing of this plate or plates. It is as follows: The working sheet, or half if you wish to look at it that way, is hooked into the anchor plate, while the other half is hooked into the quadrant. Now, if the bowsie on the boom is moved to a position so that the boom on the working side (pulling on the working sheet) is at an angle of say 70 deg. to the axis of the boat, then when we move the boom to the opposite side the gybing sheet, being anchored to the quadrant which is further away, will be pulled tight when the boom

Fig.26



is only 40 or 50 deg. over the gybing action, which as was explained in an earlier article, is a correcting action, starts early and is much more powerful and effective. Nevertheless, if the plates are put too far forward of the quadrant it may be found that the pull remains on the working sheet and is never transferred to the gybing sheet. You must experiment a little with positioning the plates before fixing them, but now you know the angles of the boom to work to it will not be found difficult.

The position of the screw eyes or pulleys marked "A" in the drawing are also important. They should be as wide apart as possible, just inside the gunwales, and in such a position that the metal ring on the boom through which the running sheet passes will pass over them as the boom swings across from port to starboard. In turn this ring should be somewhere between half and two thirds the length of the boom from the gooseneck. These features are illustrated in Fig. 27. It may have seemed a long exposition on

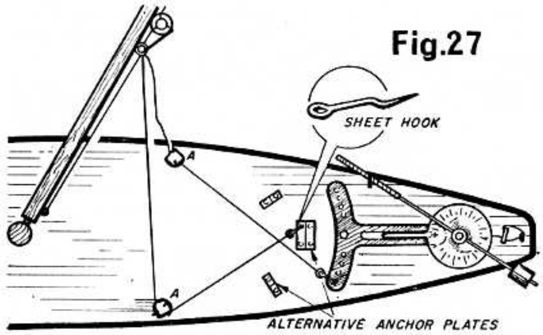


Fig.27

these proportions but the author is only too aware that while the racing skipper has found these proportions by his experience or from his club mates, the boats of unattached novices display the fixings at all the wrong places, perhaps the most common fault being the placing of the deck eyes or pulleys much too close to the centre line. The above comment of course is a good recommendation for the unattached to join a club if there is one near.

Now to finalise and describe the gybing operation in detail. Fig. 27 shows all the adjustments for a run on the starboard tack, in which the working sheet passes through the eye on the starboard side of the deck and thence to the port side hole on the centre anchor plate or the port anchor plate. The gybing sheet passes through the eye on the port side of the deck and thence across the deck and is hooked into the outer hole on the starboard side of the quadrant. With the boom holding the working sheet tight the gybing sheet will be slack. Should the boom go over to starboard in the course of sailing as depicted in 26b, the power of the wind in the wrong side of the sail is transferred to the rudder as a very strong pull on the gybing sheet and the helm given causes the boat to turn sharply to starboard to a sufficient extent to get the wind once more to the starboard side of the sail and blow the boom over to port. The strain is once more taken by the working sheet and the gybing sheet goes slack. The course followed is illustrated in Fig. 26c, in which it will be seen that, while under the action of the gybe, the course of the boat is much overcorrected to ensure that the boom returns to the right side and the true course is quickly restored under the control of the vane. Clearly if the wind is slightly from the port side all the settings are on the opposite side, a mirror image in fact.

Now when do you put these settings on your boat? While on some waters the wind is so true that the local boys never need them, these conditions are the exception rather than the rule. It is therefore advisable to put them on for all courses with the wind within 30 deg. of either side of dead astern whether carrying a spinnaker or not. It should become a habit and if treated in this way it only takes a moment—nothing like so long as reading all these words to explain it!

The Ballantyne Self-Tacking Gear

Fig. 12 gave a simple impression of this type of gear. Fig. 28 gives an exploded view in much more detail as this gear after 20 years is worthy of detailed description. Mr. Priest's *Highlander* gear described in the December 1962 *Model Maker* is his modern development of the type and is available from the Model Maker Plans Service. We are here, however, concerned with principles and designs more within the capacity of the novice.

The parts must now be becoming familiar. "A" is the rudder post surmounted by the quadrant and slotted tail, "B" the vane pintle, "C" the tubular stem carrying the main scale and pin arm to engage in the tiller slot. "D" is the main body; vertically through the centre is a clearance hole to take the tubular stem and a friction hold is obtained with a tapered cotter. On each side of the body is a pintle, one for the vane assembly "E" and the other for the counterweight assembly "F". The brackets on the front and back are for securing the top plate "G" which prevents the vane and counterweight assemblies being lifted off and the gears disengaging and gives a platform for a small scale to read the tack angle and mounting the locking lever and guying arm. The vane and counterweight assemblies are fairly self explanatory; they both have tubes with conical top bearings which sit on the body side pintles. Care must be taken to ensure that the gear segments are mounted so that with the appropriate teeth engaged the vane and counterweight arms are in line. Similar construction should be used for both so that their weights are the same which enables the weights of the vane and counterweight to be the same for balance.

To facilitate making your first gear of this type, use gear wheels of $\frac{5}{8}$ in. or $\frac{3}{4}$ in. pitch circle diameter (they must be identical), and make the body side pintles 1 in. long. The other dimensions are easily worked out from these basic ones.

The two great advantages of the Ballantyne type of gear are (1) the simplicity of balancing the gear by basic construction and (2) the fact that the gears ensure that the angular movement of both the vane and counterweight is the same, which combined with equal weights and spacing of their pintles from the main vane pintle all facilitate balancing, and balance.

The main disadvantage of this design is that the

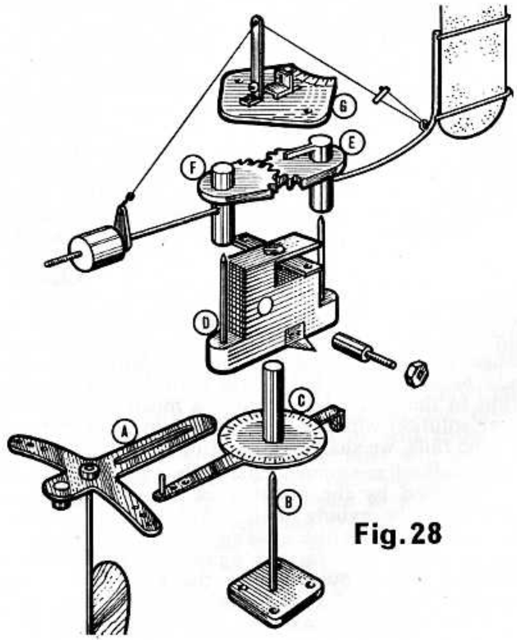


Fig.28

gear linkage between the vane and counterweight arms gives no locking movement whatsoever when the gear is in the broken condition. As with the Lassel gear "lee" is positive by the wind driving the arm against the stop. To obtain the best performance with the Ballantyne gear the sail plan must have the mast in the balanced position or very slightly forward (see the March *M.M.*) and the gear tack angle adjusted very close to 30 deg. Careful adjustment of the guying elastic as described for the Lassel gear also helps considerably with the performance of this gear.

Sailing on any course, gybing with the gear fixed and guying with it broken will all be clear by following the general details in the earlier articles.

There is of course no reason why four side brackets as shown here should not be used with the Ballantyne gear. We then come to the vane and counterweight assemblies with the pin and slot motion characteristic of the Fisher gear. The top plate arrangement of Fig. 29 enables a scale showing the broken vane angle to be readily observed; it also allows for the use of a guying/locking elastic as was described for the Lassel and Ballantyne gears. The locking lever or slide as illustrated can also be placed in this very convenient operating position. It will be realised that for commercial production it would involve more "fiddly" bits in both manufacture and assembly and no doubt these factors have influenced the very streamlined model of Fig. 30. The method of preventing the vane and counterweight assemblies of Fig. 30 type lifting off in the absence of a top plate should be noted.

The fundamental operation of the Fisher gear is, however, the same whichever model is considered.

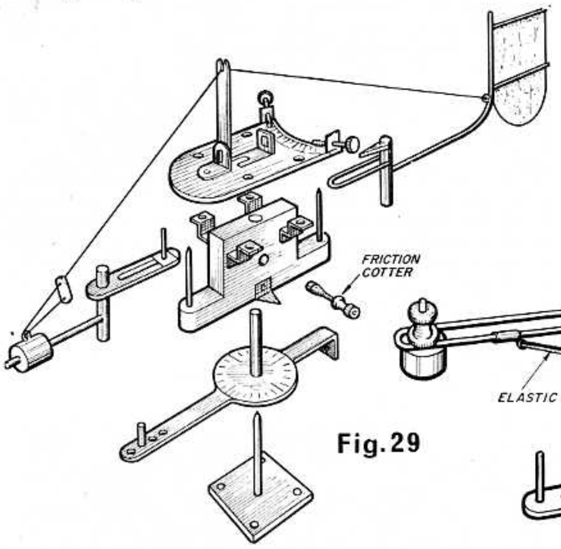


Fig. 29

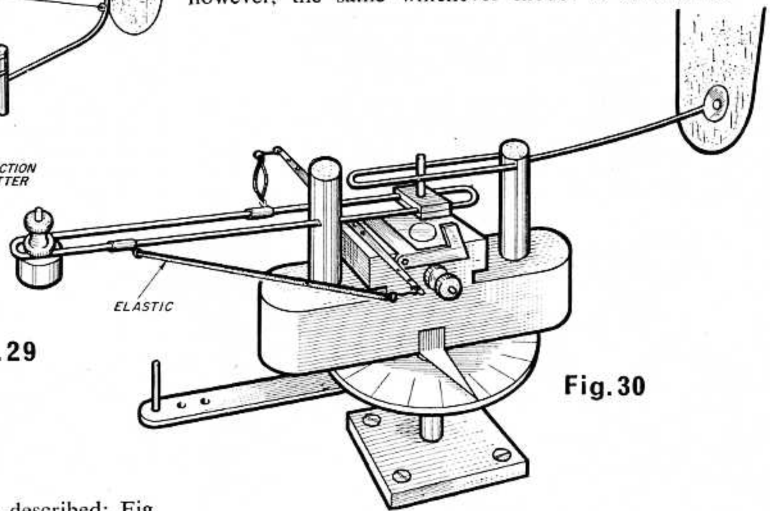


Fig. 30

THE Fisher gear is the next to be described; Fig. 13 gave a simplified illustration and, again, because it is a gear in very common use, we give an exploded diagram to enable you more readily to make one yourself.

The Fisher gear is in some respects a mixture of the Lassel and Ballantyne gears in that it uses the pin and slot motion of the Lassel and the three pintle balanced assembly of the Ballantyne. It is probably the most extensively used type of gear, but this may well be due to it being, so far as the author is aware, the only gear that has been produced commercially in this country. The number of model yachtsmen who are also model engineers is limited, but one hopes that this present series will encourage more to "have a go".

Fig. 29 shows the author's concept of the Fisher gear in exploded form. Fig. 30 shows the more conventional form that has been available commercially for some years. Both the forms and their operation will be described. The similarity of many of the features of Fig. 29 to those of Fig. 28 will be immediately seen. The quadrant with the slotted tail on the rudder post, main pintle, centre tube with scale and the main body with its side pintles are the same except that the side brackets to hold the top plate are better set near the side pintles as shown so that they do not impede the pin and slot motion.

Like the Lassel and Ballantype gears, the Fisher gives positive LEE helm by the pin being driven to the end of the slot. Weather helm is not positive, although as described with the Lassel gear, some slight locking action can be obtained with the pin in the slot. This is where some further action can be obtained from the tension of the guying elastic in the neutral or guying position of the Fig. 29 type. It is again necessary with this gear to sail with the sail plan very close to the balanced position, as would be the case for the Braine gear. The guying arrangements for the Fig. 30 design usually consist of two separate guy elastics, one on each side. The arrangements of these are legion and that illustrated using a cross bar on the body to sliders on the counterweight arm is only representative. The action of bringing a guy into operation is seldom as convenient as the arrangement shown in Fig. 29.

For new readers it is worth reiterating and illustrating the proportions for the pin and slot arms. These are shown in Fig. 31. Essentially the angle of the vane arm is required to be adjustable between 30 and 35 deg. and the counterweight arm to be as close as possible to that of the vane arm for any particular setting, without adjustments to both the slot length and the pin arm length, which is not very convenient. The proportions must be a compromise. Note that