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Some very simple devices for various oceanographical uses

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Summary—An account is given of some very simple ways of determining the underwater courses of suspension and towing lines in respect both of slope and direction. The means employed is to enclose pendulums and compasses within suitable vessels containing hot gelatine solution. These are affixed to the lines whilst the gelatine solution is hot, so that after the cooling which comes from immersion in the sea, the pendulums and compasses become immovably fixed to give the necessary records. It is shown that the devices could serve very usefully in studies of the pelagic trawl, and could be adapted to determine the shape of trawling cables leading all the way down into the greatest ocean depths.

It will be of assistance if brief reference is made at the outset to two recently published papers. In one of them (Carruthers, 1954a, 181 *et seq.*) a preliminary account was given of a simple current-measuring instrument designed for use by commerical fishermen at echo-dictated depths. With that instrument, the speed and heading of the water movement are given by the amount and direction of tilt imposed by the current upon a cone made of non-magnetic mesh metal which is hung near its apex in a smooth roller bearing carried in a sort of tuning-fork bracket. The latter is borne on and can swing freely all round a rope strained between an anchor and a buoy well below surface. To the latter is attached (for recovery) a long length of strong thin line bent to a little marker buoy which serves as a finder—the whole system being cast freely into the sea without any need for the investigating ship to anchor. The bracket holds the cone well away from the line on which it is worked.

Though, in the definitive model, the record for slope and direction is given by the operation of a simple mechanism which locks a pendulum containing a compass within itself, in an earlier model the record was got as follows:

Rigidly fastened within the cone was a wide-necked bottle made of heat-resisting glass filled half with gelatine solution and half with common kerosene. After a brief sojourn of the bottle in the sea subsequent to its having first been stood in a bucket of hot water, the gelatine solution solidifies beneath the kerosene—the slant of the firm interface then formed being that imposed on the cone by the current. The slope is easily measurable after recovery, and is of course convertible into a speed value on reference to a calibration table.

It was additionally useful to arrange for a small ring compass of aircraft type to " float " at the interface of the two hot liquids. This was easily done by affixing a diminutive buoy above the compass to the end that, when congelation took place, the direction of the tilt was preserved. The arrangement can be appreciated from the appropriate illustration which shows such a compass floating unrestrained between the two hot liquids in a glass jug (Fig. 1). In use, the bottle is of course closed by means of a cork or a screw-on metal cap made of aluminium or copper.

In what follows attention will be paid to other uses of the simple device just described which will be referred to for brevity and convenience as a " jelly bottle ".

In the other paper (Carruthers, 1954 b) an account was given of a directional wire-angle gauge designed for use on the hydrographical wire which carries the water bottles used for the routine collection of water samples and temperature data. The gauge is messenger-operated and is usable intermediately with the bottles. From it one learns the actual slope of the wire both in magnitude and direction so long as the wire is sufficiently weighted ($\nless$200 lbs) to preclude the heavy pendulous gauges from introducing local deformations into the wire because of their own weight.

We shall describe a simple method of checking the showings of such gauges—a method which could be extended to determine the underwater course of a deep-sea trawling cable leading all the way down into the greatest ocean depths. Then, it would be possible to learn the amount and direction of slope at discrete intervals all the way down such a cable as was used by Bruun from the *Galathea* when bottom-dredging in the Philippines Trench, in keeping with Kullenberg's calculations.

It should be remarked that when describing the earliest versions of the current-measuring cone above referred to, a description was added of how both direction and slope could be determined from a compass poised in hot gelatine only — without need to use the kerosene as well (Carruthers, 1954 a, p. 185).

We are particularly interested to detail simple ways of determining the underwater course of lines, wires, ropes or warps let down from stopped vessels occupied with the activities of routine oceanographical stations, or towed behind ships engaged in trawling or analogous operations. Clearly, if jelly bottles of the kind described were suitably affixed to such lines, their simple round shape would be a great boon because it would not matter how they were disposed on the wire (above, below, or laterally) so long as parallelism were maintained.

It is not overlooked that a jelly bottle whose gelatine will remain uncongealed long enough to permit slope determinations to be made of hydrowires, may have too short a liquid life to be usable for investigating the underwater course (slope and direction) of the warps on which a pelagic trawl is towed, but it will be an easy-enough matter to achieve longer timings by using greater bulks of hot jelly in bigger bottles, or by encasing the jelly bottles in suitable covers to be filled with hot water before immersion in the sea. Whatever be the form of slope indicator decided upon, neutral buoyancy will be approximated to guard against the production of local deformations in the line.

This is a matter of importance because of the great interest which attaches to deciding the fishing depth of an off-bottom trawl.

It is believed that the simple devices here being considered could be profitably used to find at what depth a pelagic trawl had fished, at what height above bottom its foot-rope had ridden, what had been the distribution of its vertical gape and of its horizontal gape.

We have here no concern at all with the very ingenious instruments which use electronics and acoustics to telemeter net depth back to the towing ship whilst the tow is in progress, but fully appreciate the value to a fishing skipper of always knowing at what depth his pelagic net is fishing, so that he can alter his speed or warp length to keep it at the depth where his echo sounder tells him the fish are.

Because it seems quite unlikely that ordinary fishing craft will ever carry the telemetering net-depth indicators now being tested, it has seemed well worth while to line up with opinion that a necessary pre-requisite to achieving anything simpler which can be relied upon, is to determine the exact underwater course of the towing warps all the way from ship to net.

Though insufficiently acquainted with the latest achievements of Dr. J. SCHÄRFE of the Net Research Institute at Hamburg, who has carried out some very interesting investigations of the pelagic trawl with the aid of instruments specially developed for the purpose (SCHÄRFE, 1953), the writer knows of no such determination ever having been made as yet, but there seems no real need for the complexities of a recording instrument which would travel all the way along the warps to effect it. It seems amply good enough to measure the slope of a warp at a lot of discrete points where slope alone is the matter of interest, and to measure slope *and* direction at many points along the two warps where both slope and separation (roughly telling net gape) are wanted.

It could well be that, after learning the average slope of the whole warp lengths for different speeds of tow and various lengths of warp veered (which average slope would reveal fishing depth), it might be found possible to apply " corrections " to the readings of the deck inclinometer used to measure the entry angle of the warps. It is worth hoping that such " corrections " could become known for all lengths of warp out and all towing speeds so that the easily observed entry angles could be converted into approximate mean slope values and a table of implied net depths consulted with confidence.

WARP SLOPE

Where only one cable towed astern is being investigated, the rectangular instrument pictured (Fig. 2A and 2B) is a suitable and convenient one to use. It is a slender box of about cigar-box size and shape with front and back of clear perspex and is filled with gelatine solution only. Inside is a pendulum which can move freely so long as the gelatine solution remains liquid after prior immersion of the instrument in a bath of hot water. It is intentionally not fitted to the warp or towing rope by clamps, but through the medium of the bracket shown, which is secured on the warp, thin wire, or rope, by winding round it and the warp a strong stretched rubber thong, just as a runner bean in the garden winds itself on to and up its supporting stick.

Using such a cheap and easy method of attachment, one can affix all manner of instruments to all sizes of wire, cable, or rope and secure a firm non-slip grip without trouble.

The rather heavy inclinometer is pictured fastened securely on to a very smooth brass wire no thicker than ordinary water-bottle wire. To facilitate attachment by one person working alone, the side of the bracket which is bound on to the warp has since been fitted with prongs after the manner of the wooden rods fixed across the tops of some of the bottles pictured. This makes it very easy to effect attachment by winding a lot of stretched office rubber bands round and round bracket-rod and warp in an obvious manner.

It does not matter if the warp twists at all because the rectangular inclinometer as pictured can swing all round it and still maintain parallelism—just as the passenger cages of the " Big Wheel " at a fair move round its axle.

There is a filling point (unscrew the domed knob) and also an air vent controlled by a removable grub screw. Inwards thumb and finger pressure exerted on the two small spring-loaded levers either side of the filler knob releases the rectangular box from its bracket.

The idea is to have a battery of such inclinometers standing in a bath of hot water on deck with their brackets alongside as the cable is veered. With such a situation the brackets are simply affixed and the boxes no less easily clipped in. This inclinometer has worked well in tests and has congealed conveniently in about 20 minutes, but it would be improved by being made semi-circular to avoid preferential congelation in the corners, and should be lighter.

If used on the warps of a trawl being towed, there will be some lateral pressure on the box on account of the warps not leading dead astern. The rectangular inclinometer might not remain completely pendulous under such circumstances unless unduly weighted along its bottom edge. The result might be that the pendulum would not then give the true reading for slope which it provides when towed dead astern. If round jelly bottles be used as slope indicators however, there can be no difficulties due to any rolling out of a pendulous position. If the need be to use them on a thin stranded wire of water-bottle type, they can be used in clamp-fitted holders, as was kindly done for the writer aboard the German research vessel *Gauss* by Dr. Joseph in March 1955, during a cruise in the North Sea. Two results obtained by Dr. Joseph are pictured (Fig. 3). The slope of the firm slant interfaces which can be very clearly seen was measured with ease by means of a simple goniometer made specially for the purpose.

Dr. Joseph towed a terminally-weighted wire astern with six of the clamp-fitted jelly bottles affixed at equal intervals along its underwater part. The clear results he got revealed overall downwards concavity of the curved wire with increase of slope towards the weight.

On another occasion he streamed a buoy astern on a considerable length of wire with a weight hung on about half way along it. Jelly bottles spaced equally, four on each side of the weight, revealed very clearly the opposite slopes of the two halves of the wire. Between the ship and the weight the wire took on a downslope very little removed from straight, though with a very slight downwards concavity. From the weight to the buoy the wire sloped fairly steeply upwards with a very pronounced upward concavity.

The results will be reported upon in detail on some later occasion when more have been added.

The two bottles pictured (Fig. 3) had been used on opposite sides of the weight, which was hung midway along Dr. Joseph's towed buoy-line. With his jelly bottles the writer has preferred not to use clamps for attachment purposes, but to employ the same sort of method as was described above in connection with the rectangular inclinometer. To do so avoids limitation of use to one sort and size of line.

An accompanying picture (Fig. 4) shows two jelly bottles after use in experiments recently conducted in the Crouch estuary from a research vessel belonging to the Ministry of Agriculture and Fisheries. Mr. D. Waugh of the Burnham Fisheries Laboratory very kindly afforded the facilities and gave yeoman assistance. In this picture the convenient goniometer made by Dr. Joseph for measuring the jelly slopes is also to be seen.

The jelly bottles illustrated are of the usual heat-resistant glass and are of the compass-containing type. To affix them easily to lines of any size or nature the following was done:

A convenient length of clean, strong and heavily-lacquered wooden dowel rod was

Fig. 1. For explanation see text.

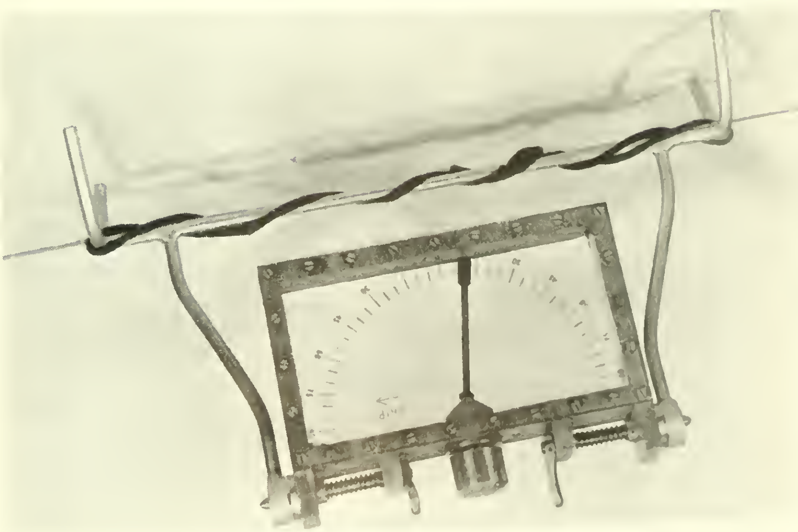


Fig. 2A. For explanation see text.

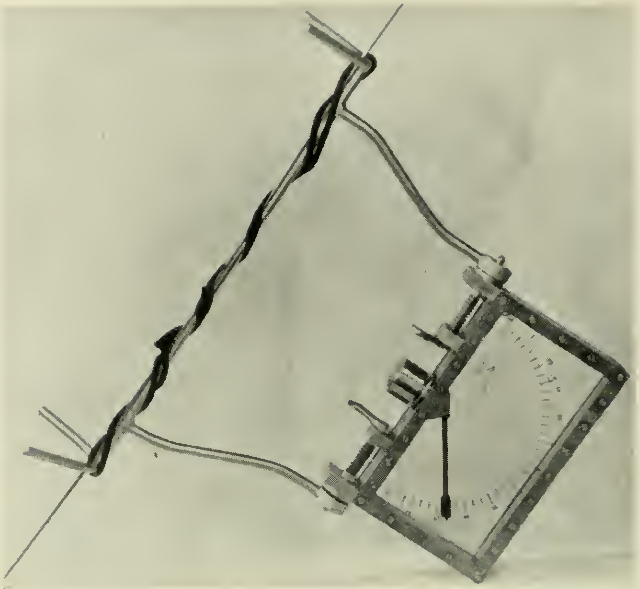


Fig. 2B. For explanation see text.

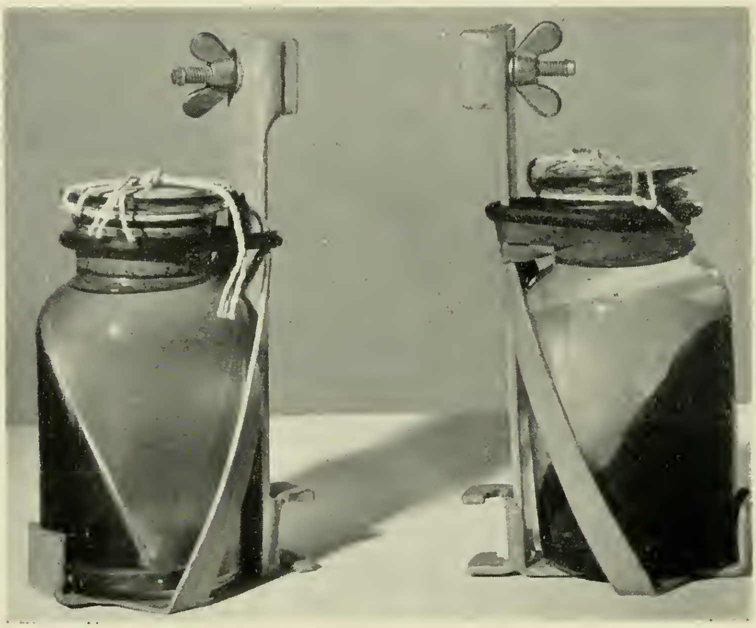


Fig. 3. For explanation see text.

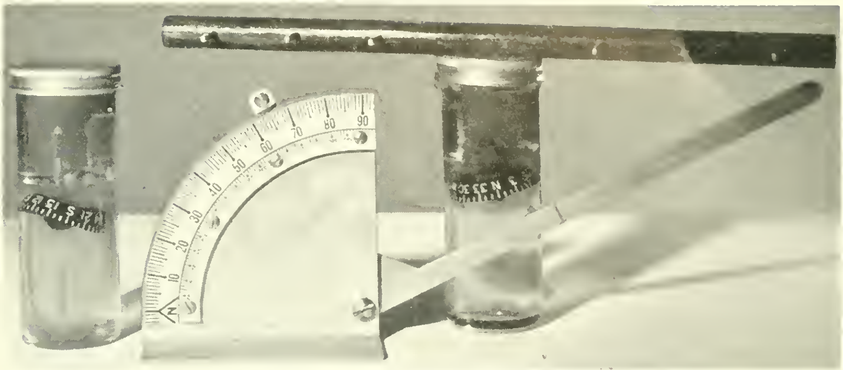


Fig. 4. For explanation see text.

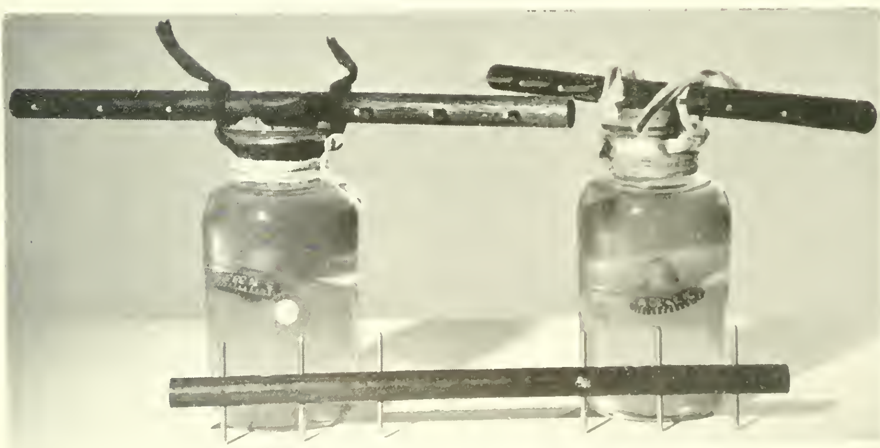
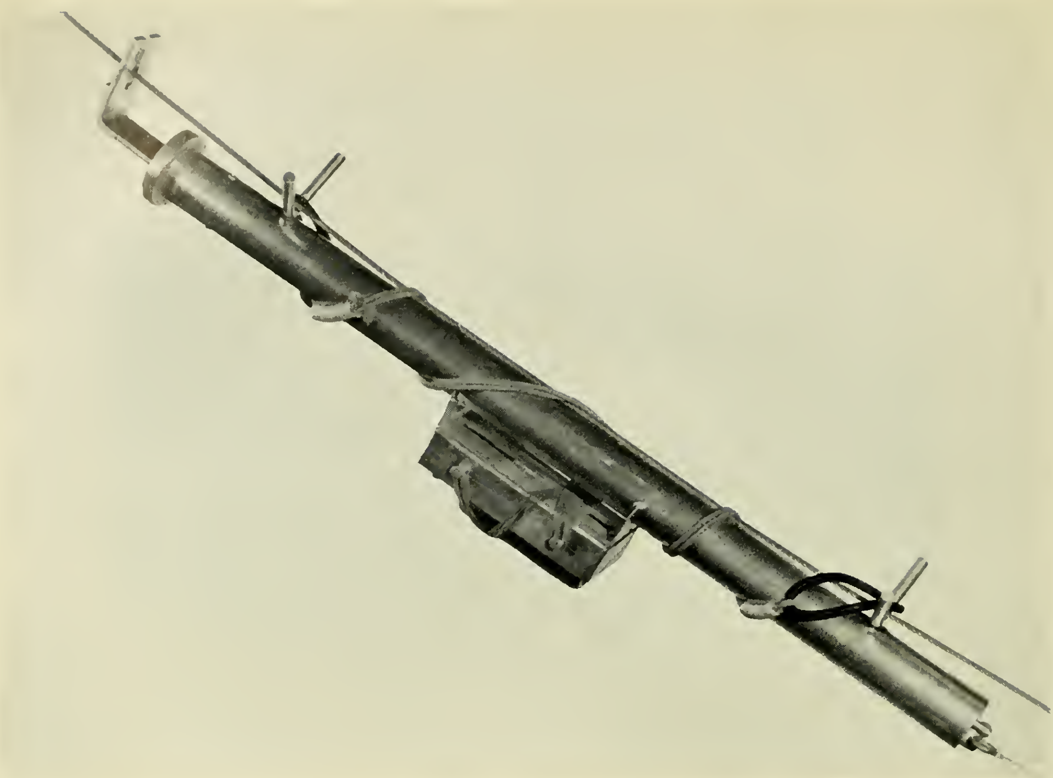


Fig. 5. For explanation see text.



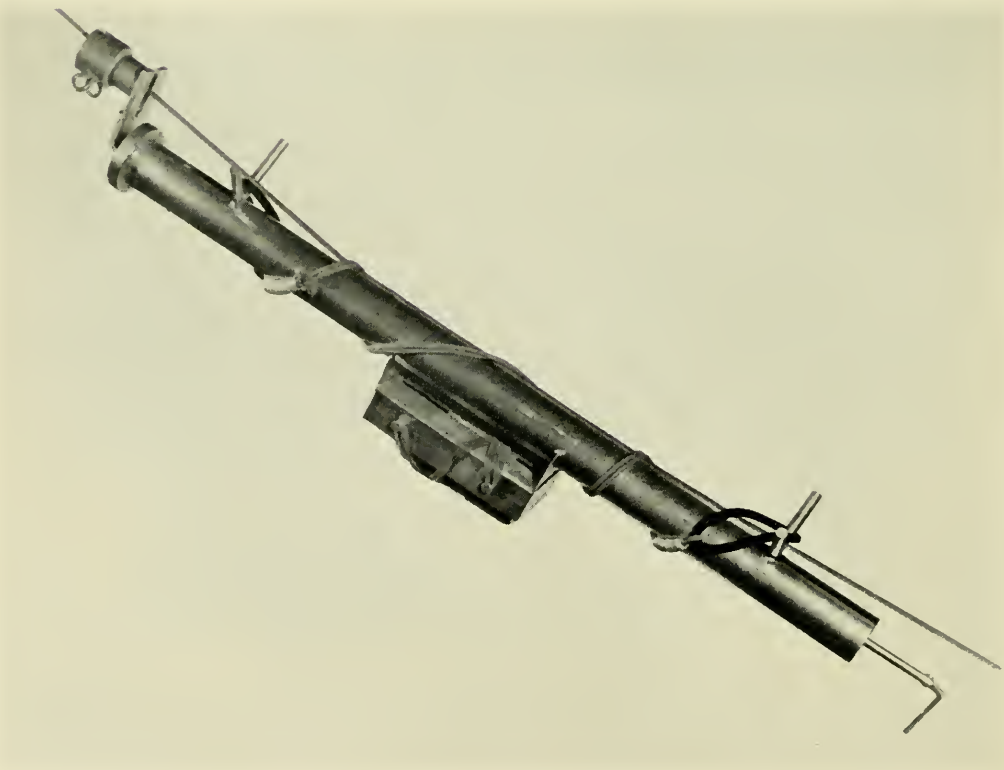


Fig. 6A and B. For explanation see text.

fastened immovably and diametrically across the top of the aluminium screw-on closure cap. This was effected by riveting on from the underside. In the cap is a disc of kerosene-resistant artificial rubber. On both sides of the disc the round wooden rod has had thin but stiff metal bars driven through it to present prongs projecting equally either side. Such a rod can be seen illustrated in another of the pictures (Fig. 5).

With this convenient arrangement all that is necessary to effect secure attachment is to hold the bottle-carrying rod against the rope, wire or cable with one hand, and to hook good quality office rubber bands on to the individual prongs in succession—stretching them, winding them whilst in tension round rod and cable, and hooking their other ends on to whatever prong offers to hold them tight.

The last-mentioned picture (Fig. 5) shows a pair of compass-containing jelly bottles which had also been used in the Burnham experiments. In this case the bottles are wide-necked pyrex bottles which are a standard list item of laboratory furnishers. With them, the attachment rods were secured on to the cork closure bungs by means of slender washer-loaded bolts and small nuts.

Various additional (and much more elegant) mountings for the compass-containing jelly bottles were made by Mr. A. J. WOODS of Messrs Kelvin & Hughes. He has been associated with the writer throughout the experiments, and is making improved devices (to be spoken of below) in the course of continuing collaboration.

The excellent little aircraft ring compasses used in the experiments were made and kindly loaned by Messrs. Kelvin & Hughes. For reasons of cost and space Mr. WOOD'S additional mountings are not illustrated in this article, but it should be mentioned that the two extra kinds which he constructed both made use of a pronged attachment bar and rubber bind-on bands. One of them simulated the " Fair Wheel " characteristics of the bracket-mounted rectangular inclinometer earlier described (Fig. 2A and 2B).

APPLICATION TO PELAGIC TRAWL INVESTIGATIONS

Because there is a likelihood that commercial fishermen of future years will find an ever-increasing need to operate on the stocks of non-bottom fish living in deep-water oceanic areas, it is probable that the passage of time will invest pelagic trawling with more and more importance.

From inquiries made of fisheries research experts who concern themselves with the modern one-ship pelagic trawl, need exists to know much more than is known at present about it.

In the course of the experiments carried out in the Crouch estuary with jelly bottles, a situation resembling " fishing in reverse " with such a net was staged. Under Mr. WAUGH'S direction two boats were anchored a measured distance " X " apart across the stream, and a line some " 2X " (and other multiples of " X ") long was streamed from them—with one end secured at each boat and a large plankton net plus other drogue objects attached to the mid-point of the line.

In such circumstances, with a series of compass-containing jelly bottles secured on to each half of the streamed line, it should be easily possible to determine the mean angular divergence. By multiplying the total length of the line into the sine of half that angle, one should get a value equal to the distance of separation of the two anchored boats.

There were a few difficulties during the tests as can readily be imagined. For instance, a strong pull by the drogues must urge the boats to close somewhat on each other, whilst less than a really strong pull must leave the lines bowed to some extent. Nevertheless, the results were amply good enough to invest the application of the idea to studies of the pelagic trawl with real promise.

Certain full-scale experiments are envisaged thanks to expressions of interest and the promise of facilities from the two British fisheries laboratories. Of an ample assemblage of the compass-containing jelly bottles, half would have their " upperworks " enamelled red for attachment on the port warp, whilst the other half would have green floats and would go on the starboard warp.

In a first investigation the average overall downslope of both warps will be worked out from the mean of the jelly slopes, and the fishing depth of the net estimated accordingly. From the compass readings of the bottles the course of the warps as projected on the sea-floor will be derived and an estimate of the horizontal gape of the net made.

Apparently Dr. Schärfe holds the view that useful conclusions as to horizontal net gape can even be made from noting only the separation angle of the warps behind the slip hook. This he does by means of his special device the " Spreizmesser ".

Since the investigating ship will have an echo-sounder the net tests could be done in a chosen area with a flat bottom so that it could always be known that the foot-rope would never be higher off bottom than a distance " H ". If, when the net was shot, a length of thin Kelvin wire of length about $1\frac{1}{2}$H or 2H carrying an object like a smooth cannon-ball at its free end were hung from the bottom of the net, then, if several jelly bottles went down on this wire, one would learn on hauling what its slope had been and so would know how high above bottom the foot-rope had ridden during the tow. One would then have data enough to make an estimate of the vertical gape of the net. In a subsequent investigation much better things will be attempted:

A drogue of nearly neutral buoyancy will be towed inside the net from the midpoint of a light line of not much greater length than the distance the net doors would be apart if the net were stretched out tight on the quayside. An array of compass-containing jelly bottles on each half of such a line will give a much better triangulating situation with sound promise of an acceptable determination of horizontal gape.

How the same sort of thing could be done to investigate vertical gape at different points will readily suggest itself.

For some of the determinations the jelly bottles would not need to contain compasses.

The need to weigh a few considerations has led to postponement for the time being of the full scale net tests from a fisheries research vessel. For one thing there is the need to hit upon a long-enough timing (congelation period) as already stated. Then, although one could not possibly devise any other slope and direction indicators as simple as the jelly bottles, it is a fact that difficulty attaches to reading the compass directions precisely enough when (as so often must happen) the compasses are not on an even keel but are awkwardly canted.

Where slope only is needed, recourse will be had to a gelatine-filled perspex cylinder containing a rolling clinometer furnished with a finger which travels over a protractor. With this device (now being made), there will be no need for two liquids and no need to measure jelly slopes with an external goniometer.

At the time of writing this there is also being made (by my collaborator, Mr. A. J.

Woods of Messrs Kelvin & Hughes) an instrument which is in effect a rolling clinometer containing a compass which will always remain on an even keel. This also will be contained in a perspex cylinder filled with gelatine only, and it too will have a contained protractor permitting slopes to be read to one degree or so. Its compass will be pivoted and not dependent upon buoyancy of a small float. This is an advantage because no depth limit will apply as it might if risk existed of a float being compressed by water pressure to a state of nil buoyancy. When these devices have been fully tested and made in sufficient number, the full scale net tests will be embarked upon without delay and with confidence. Sight will not be lost of the need to ensure that the compasses are held a sufficient distance from the warps to escape any disturbing influence of the latter.

So far we have discussed mainly the measurement of slopes of modest magnitudes below the horizontal. We turn now to slopes measured as departures from the vertical.

OFF-VERTICAL SLOPES: THE UNDERWATER COURSE OF DEEP-SEA WIRES AND CABLES

Our first concern was to establish a means of checking the showings of the wire-angle gauge to which earlier reference has been made above (Carruthers, 1954 b). The need is to discover whether the pendulum gives a true value for the slope of a hydrographical wire (with its load of water bottles) when the observing ship is somewhat lively. It was decided to use jelly bottles to make an adequate series of tests.

The first requisite was to devise a way of using them on the hydrowire without interfering with the operation of water bottles and the wire-angle gauges at the same time. The way chosen was to construct a simple " messenger-passer " easily attachable to the wire and able to carry a compass-containing jelly bottle held firmly parallel to the latter. It would then only be necessary to fit the fall-away messenger hung beneath such a device with an extra-long lanyard, to enable the two German clamp-on jelly bottles (Fig. 3) to be used as well as the compass-containing jelly bottle. This latter would be housed in a sort of little sentry box attached to the " messenger-passer ". Such an arrangement would furnish three jelly slope values and one direction reading for comparison with the readings of the wire-angle gauges under test.

Illustrations of the simple instrument made by Mr. Woods to the writer's design are presented (Fig. 6a and 6b). The first (6a) shows the situation before the arrival of a messenger from above, i.e. with the fall-away messenger still hanging beneath. The second (6b) shows the situation after the strike of the messenger from above, i.e. with the fall-away messenger gone down to trip other instruments below.

The device consists of a brass tube attachable by stretched rubber thongs to the hydrowire. Running down its interior is a flat bar of brass with a small hinged piece at its lower end. So long as this is bent upwards and contained in the tube, a messenger can be hung from it, but as soon as the central bar is pushed down to full extent the messenger must fall away. The central bar is bent over at the top as shown, and is forked to receive the wire. A length of it near the top of the tube is slotted, and through this slot a short length of thin glass rod can be passed and seated in a cupped collar at the top of the tube. The glass rod takes the weight of the internal bar and the hanging messenger when the device is cocked. The impact of a messenger from above infallibly breaks the glass rod and lets the pendant messenger fall away.

The compass-containing jelly bottle is housed in the little fastened-on brass box discernible on the face of the tube. A fin fused on one side of the bottle seats in a slot cut into the tube to provide direction fixation, and the bottle is held firmly in place by means of rubber bands as illustrated.

Six fathoms of water in the River Crouch afforded enough messenger travel for two wire gauges to operate with the " messenger-passer " in between them. The latter always functioned without fail. At the time of writing this the deep-sea tests to check the showings (pendulum behaviour) of the wire-angle gauges in the manner described, are in progress aboard the Royal Research Ship *Discovery II.*

If it were desired to observe the slope magnitudes and directions of a thick trawling cable leading all the way down to a trawl or dredge being dragged over the deep ocean floor, it would not be possible to use jelly bottles for time reasons. Also, any messengers for the use of which a devised method might call would necessarily have to be of rather mammoth size—each one something like a yard of heavy iron tube split and hinged to go on the cable. It is suggested that a simple " messenger-passer " after the style of that described could be made " rough, long, and strong " with a thin tight metal rod of water bottle wire diameter held a small distance off from it (but parallel to it), strained between two short spurs projecting out at right angles respectively at top and bottom. If such crude devices were fastened on to the cable at desired intervals in the manner already described, a wire-angle gauge could be operated at the bottom of the thin offset rod in each case. This could be done quite simply if, when a giant messenger struck to break the short length of thick glass rod or small phial which would be necessary in such case, a daughter messenger of ordinary weight and size were released to run down the offset rod to trip the gauge quite harmlessly.

OTHER POSSIBILITIES

In spite of the wide variety of current-meters already in existence, there remains a real need for one which could be used to make all-weather absolute observations of near-bottom currents from anchored vessels. The numerous and very convenient lightships are in mind. The problem has always been how to get acceptable records from a lively ship, and the suitable use of jelly bottles suggests itself as offering escape from the difficulties imposed by ship movement, because they would be self-damping systems.

If a length of Kelvin wire carrying a heavy terminal plummet were let down from a lightship, it would be easy to stream tow-nets from it at any desired depths. The nets could be made of very wide mesh fishing net near their mouths, and the rest of stramin. If streamed on up-and-down bridles the rings would not rotate. In such case there could be a horizontal diametric brass rod across each net mouth, and on it could be hung a semi-circular swinging plate carrying a compass-containing jelly bottle suitably mounted on its reverse.

Using some such simple arrangement with limp connection to the suspension line, absolute measurements of currents could, it is held, be acceptably made during quite bad weather. Such a method is well worth trying because of the great opportunities which exist for working from anchored vessels. The necessary calibrations would, of course, have to be made against logship runs. When the compass-containing and depth-ignoring rolling clinometer spoken of above becomes available with slope-reading possible to one degree and compass always on an even keel, the possibilities will be greatly enhanced. Then, the simple current-measuring instrument envisaged should be able to give good service used from a moving ship, to reveal currents differences between small and great depths.

It remains only to remark that such simple congealing inclinometers with direction-indicating powers as are being made, could be very usefully employed in non-captive instruments sent down to the ocean depths to record the bottom water movements there. The working principle would be that of the bathygraph of EWING and VINE, which achieves self-ascent under the lift of an oil-filled balloon after the detachment of ballast left on the ocean floor. This is of course the principle of Professor PICARD's bathyscaphe but, as EWING and VINE remark, " the problem of locating the apparatus after it has reached the surface is a serious one ".

ACKNOWLEDGEMENTS AND NOTE

Thanks are expressed to Mr. A. J. WOODS for his very valuable collaboration and instrumental ingenuity; to Mr. D. WAUGH for generous help when carrying out tests; and to Doctors BÖHNECKE and JOSEPH for trials made aboard the German research vessel *Gauss*.

Though this is perhaps a strange finish to a paper such as the foregoing, the writer is obliged to remark that the jelly bottles come specifically under the coverage of a patent which runs in most countries having important fisheries. The patent in question relates to the Current Cone for which the licence holders are Messrs Kelvin & Hughes. From them the final models of the slope-and-direction indicators will presumably be procurable in due course.

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