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The Lay of Rope

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The Lay of Rope

> *A hawser-laid rope is composed of three single strands, laid up right-handed or with the sun.* Darcy Lever (1819)[1]

What did Lever mean by right-handed laid rope and why was this lay preferred by ropemakers? Figure 1 shows hemp fibres (A) being *spun* right-handed as yarns (B), and these in turn being *formed* left-handed into strands (C), which are *laid* right-handed into ropes (D). By *closing* three ropes, we get a cable (E). Ashley says that these technical verbs are preferred by ropemakers, but comments that they are 'often used indiscriminately'.[2] As a preface to what follows, I imagine that many people would feel that the meanings of terms like 'with the sun', 'clockwise' or 'right-handed' are self-evident, and follow some sort of onomastic natural law. In fact, they only make sense if we are told from which side of the rotational plane the movement is observed. Put more simply: point of view matters. The sun rises in the East and sets in the West, but as seen in figure 2, seen from a point above the North Pole, the earth is rotating counterclockwise, while from a corresponding point above the South Pole, it is moving clockwise. At higher latitudes, as one faces the sun, it travels across the sky from left to right in the northern hemisphere, and from right to left in the southern hemisphere. 'With the sun' is an old-fashioned alternative to 'clockwise', but when used it is tacitly assumed we are north of the equator. The arrangement of the numbers on the face of one's wristwatch is not arbitrary but reflects the system used on the clock's predecessor, the horizontal sundial, as seen in figure 3A. In the northern hemisphere the shadow of the gnomon moves from left to right, as seen by an observer looking north, that is to say with his back to the sun. If the sundial is mounted vertically like that in figure 3B, the shadow moves the opposite way.[3] Because the terms 'right-hand' and 'left-hand lay' occur so often in what follows, we will for convenience

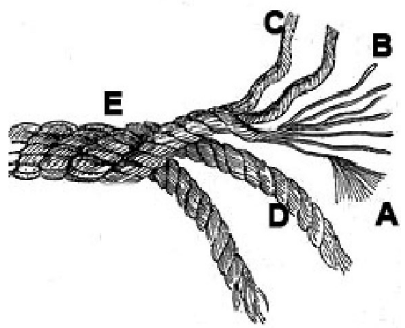

Figure 1 Cable dissected (Author's sketch)

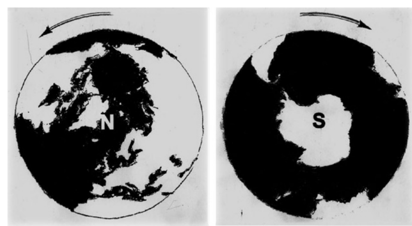

Figure 2 View from above the poles (Author's sketch)

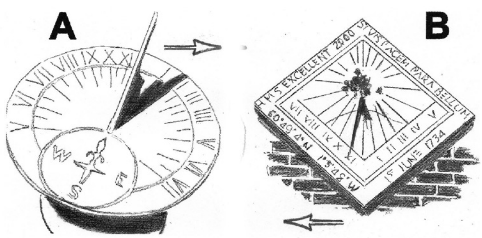

Figure 3 Sundials (Author's sketch)

1 Lever, *Young Sea Officer's Sheet Anchor*, 2.
2 Ashley, *Book of Knots*, 23.
3 Some medieval astronomical clocks like that at Münster cathedral do, in fact, read counterclockwise to match the movement of a wall-mounted sundial.

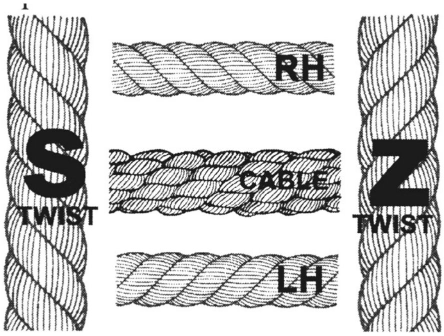

Figure 4 Z- and S-twist (Author's sketch)

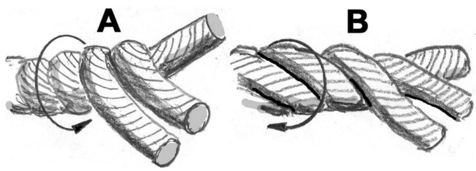

Figure 5 The spirality of a rope from the cut end (A) and along the rope (B) (Author's sketch)

shorten them to RHL and LHL. A RHL rope is commonly defined as one in which the lines dividing the strands run down and to the right if horizontal, up and to the right, if vertical, as shown in figure 4, with a comparable definition for LHL rope. The terms Z-twist for RHL and S-twist for LHL rope, are often preferred nowadays, but note that these aids to memory work only if the rope is vertical. Furthermore, we have to be quite clear that a mnemonic is not an explanation.

The terms RHL and LHL are clearly understood by seafarers, but this arises simply from tradition and convention and a consensus to accept this terminology, not because of any intrinsic overarching 'handedness' principle. Despite its use by Lever, references to RHL and LHL, only become common in seamanship textbooks from about 1850, replacing, or in parallel with, the earlier terms, 'Hawser-laid' and 'Cable-laid'.[4] The choice of term may have been influenced by the 1841 standardization of machine-screw threads by Joseph Whitworth.[5] As an aside, hawser-laid definitely has the same meaning as RHL, but according to Smyth, the term hawser, meaning 'a warp intermediate in size between a cable and a tow-line', rather curiously, was cable-laid.'[6] In America, the term hawser-laid was widely synonymous with cable-laid, for instance: 'Hawser- and cable-laid rope is all the same'.[7] A cable was almost always formed of three ropes, but I have one reference to one made with four, called a 'Cable-laid stay'.[8] For the most part, the sea languages of other nations, follow suit. In German, *recht-geschlagen (Kardeelschlgen)* = right-hand and *links-geschlagen (Kabelschlagen)* = left-hand laid, mean exactly what we would expect, but as this Swedish citation makes clear, there were exceptions: 'Note that such left-hand laid rope (against the sun) has the same spirality as a right-handed screw. It is actually called 'right-handed' in English, because they are naming it for the twist of the finished rope, while Swedish ropemakers name it for the way the rope is twisted during manufacture'.[9]

My own epiphany about the importance of point of view in this context occurred 70 years ago. Instructor Chief Petty Officer Finch had explained to us training ship recruits: 'A hawser is composed of three single strands, laid up right-handed.' We were all holding bits of rope in our hands and I was unwise enough to ask: 'But Chief, aren't the strands twisting up left-handed?' This was not well received, but I did learn an invaluable lesson. In the navy, when struck by a bright idea, there is much to be

4 Less commonly *plain-laid* and *water-laid*.

5 It is generally believed that the preference for right-hand screws is explained because it is easier for a right-handed person to drive in a screw with a right-handed (supinatory) twist, than using the reverse (pronatory) motion.

6 Smyth, *Sailor's Word Book,* 374.

7 Brady, *The Kedge-Anchor,* 42. See also Harland, 'Hawser laid/Cable laid', 470–1.

8 Hammersley, *Naval Encyclopedia,* 699.

9 *Märk att sådant vänsterslaget (motsols slaget) tågvirke har samma spiralvridning som en högergängad skruv. Det kallas också på engelska righthanded, emedan engelsmännen namnge det färdiga repets spiralgång, medan svenska repslagare alltid namnge repen efter vridningen vid tillverkningen.* Svensson, *Handbok i Sjömans Arbete,* 20.

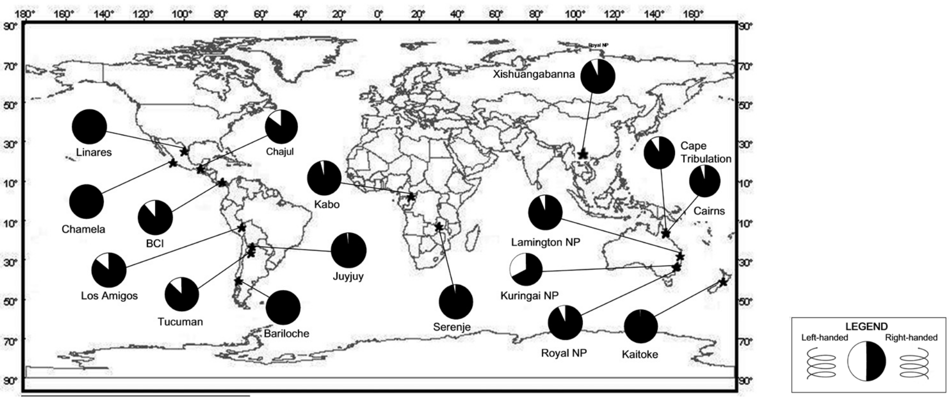

Figure 6 Twining vines: the white segments show the small proportion of left-handed twists (Courtesy Dr Will Edwards and Dr Angela Moles)

said for keeping it to oneself. Figure 5 makes clear why we were at cross-purposes. Looking directly at the cut end of the rope (A), the strands are laid up counterclockwise (left-handed). By convention, the observer looks along the length of the rope towards the end (B), with the strands twisting up clockwise.

Right or left lay? Our asymmetrical world

In 2003 R&W Rope of New Bedford supplied 27 miles of RHL rope, to rig the replica frigate featured in the film *Master and Commander*. At the time it was asserted that this was anachronistic, in that the rope would have had a left-hand lay in Napoleonic times.[10] This claim is patently incorrect, but it does raise the question why the rope would have had a particular lay in the first place, and why, apart from cable-laid cordage, left hand rope is virtually unknown. In fact, this just confirms the inherent asymmetricality of our world, with imbalance being the rule rather than the exception. As Pasteur put it: *L'univers est dissymétrique*;[11] and the phenomenon is beautifully illustrated in nature by a study on twining vines, which showed that 92 per cent of climbing vines spiral upward in a right-handed twist, as shown in figure 6.[12]

If twine direction occurred at random, then half the vines would twist one way, and half the other, and since the 92 per cent figure was true in both hemispheres, we can rule out relationship of the vine to the sun's movement, or the Coriolis Force. The investigators concluded that it was best explained by the asymmetrical, left-handed molecular structure, of the plant's protein building blocks, which like their constituent amino-acids are virtually all laevo-rotatary, that is to say, they deflect a beam of polarized light to the left, as seen by an observer looking toward the beam.[13] The authors equate 'counterclockwise' with 'right hand twist', underlining that while 'with the sun', 'clockwise' and 'right-handed' mean the same thing in the maritime world, this does not apply in some other fields. As Chris McManus comments: some scientists – botanists in particular – have chosen to call a 'right-hand spiral one . . . which most people would like to describe as left-handed'.[14] The twining phenomenon prompted me to wonder if there might be an inherent molecular asymmetricality in hemp fibre that would explain why RHL was superior to LHL. In fact, with the benefit of electron microscopy, we know today that hemp fibres do indeed

10 www.imdb.com/title/tt0311113/trivia.

11 Louis Pasteur in a discussion at l'Academie des sciences, June 1874, Vallery-Radot, *Ouvres de Pasteur*, vol. 1, 361.

12 Edwards et al., 'Global trend in plant twining direction', 795–800; Macey, R. 'Vine story has a puzzling twist', *Sydney Morning Herald*, 27 Aug. 2008; Angela Moles ABC interview: www.abc.net.au/catalyst/stories/2400092.htm

13 Angela Moles, pers. comm.

14 McManus, *Right Hand, Left Hand*, 48.

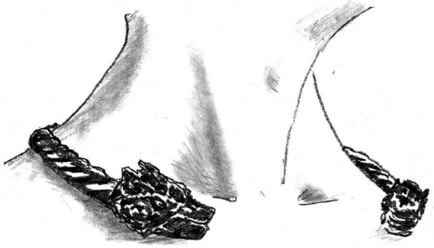

Figure 7 Typical style of an Iron Age torc. (Author's sketch)

have an internal spirality (chirality), and there is a low-tech test, based on the direction wetted fibres of flax and hemp twist as they dry out, reflecting the opposite molecular chirality of the two fibres, which demonstrates that flax has an equal and opposite spirality to hemp.[15] It is not impossible that some bygone ropemaker might have stumbled across this phenomenon and deduced that hemp had an internal twist, but there is no evidence that this occurred. Had it made a practical difference, I have no doubt at all that the old-time craftsmen would have discovered it, since any thought that these chaps were less intelligent than we are is a mistake. In any case, theoretically interesting as this is, the angle of spiral in both flax and hemp is only about ten degrees, too little to have any practical effect.[16] Another possibility would be that right-hand spun yarns, the building blocks of right-hand rope, were somehow easier for primordial spinners to make. The evidence is slender, and if anything, contradicts this theory. In its simplest form, the early Iron Age necklace known as a torc or torque, consisted of two wires twisted together. The majority of surviving examples of these are laid up left-handed, as in figure 7, and this predominance can be explained because a right-handed person securing two wires with his left hand, will find it more natural to twist them left-handedly with the fingers of the right hand. It is easier to push the thumb away from the opposing fingers than it is to move it towards the little finger, because the abductor muscles of the thumb are stronger than the adductors.

15 Wiener et al., 'Differences between flax and hemp', 58–63.

16 Stephen J. Eichhorn, pers. comm.

Figure 8 Spinners (Useful Arts and Manufactures)

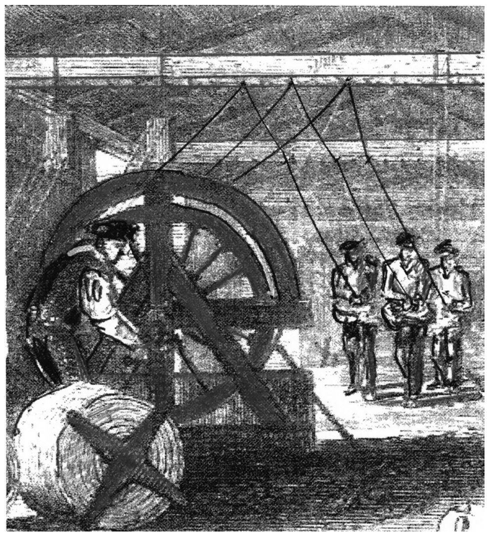

Figure 9 Ropewalk (Useful Arts and Manufactures)

Nineteenth-century spinners wrapped bundles of hemp around their waists,[17] as shown in figure 8, plucked out some fibres to form a yarn, and secured this to the whirls or hooks of a spinning wheel, and then walked backwards down the ropewalk as shown in figure 9, adding fibres to the yarn which was spun up right-handed. Was it somehow easier to

17 The bundles sometimes referred to as 'tows of hemp'.

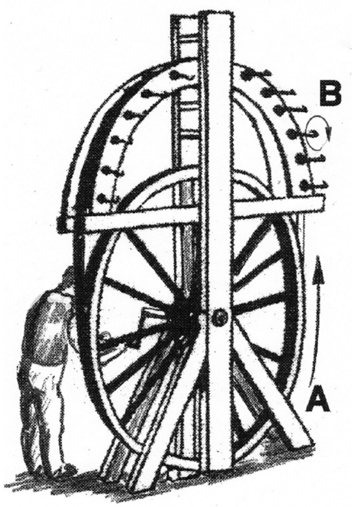

Figure 10 Spinning machine (Author's sketch)

twist yarns in this direction? We can say with certainty this was not the case, because twist was entirely determined by the direction the wheelman turned the large wheel (A) of the spinning machine shown in figure 10, with the whirls (B) turning in the opposite direction.[18]

Left-hand laid rope

My conclusion is that RHL predominates, not for any specific reason, but simply because ropemakers have always made it that way. In most maritime applications the lay of the rope doesn't matter in the least, but LHL ropes were in fact produced for some purposes, starting of course with cable-laid cables, laid up by twisting three RHL ropes left-handedly, as seen in figure 1. Cables were used for the heaviest stays and shrouds and for anchor-cable. There are few detailed contemporary references to LHL, but we can offer a couple: Luce describes back-handed rope as follows:

> In making the plain laid, it was said the readies (strands) were left-handed and the rope itself right-handed. If instead, the ready is given the same twist as the yarn (right-handed), when brought together and laid up, the rope must come left-handed. This is left-hand or backhanded rope. It is more pliable than plain-laid rope, less liable to kinks and grinds when new, and is allowed in the navy for reeving off lower and topsail braces.[19]

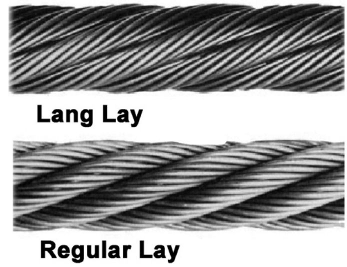

Figure 11 Lang lay wire rope (Author's sketch)

Burney gives a similar description for cordage used with gun side-tackles:

> *Gun Gear* is hawser-laid three-stranded left-handed rope, generally termed *reverse-laid rope*. The yarns and strands being laid up right-handed, and the rope left-handed, renders it soft and more easy to handle; for all it is not so durable, as it is more apt to admit the wet and cause it to rot.[20]

Neither of these are true mirror images of RHL rope, but it would be difficult to distinguish the difference between this and back-laid rope without careful examination. Ashley comments that 'Lang lay' wire rope was constructed in a somewhat similar fashion.[21] The difference is that instead of yarns and strands having the same twist, strands and wire rope have the same twist, as shown in figure 11. John Lang patented this arrangement in 1879, claiming it wore better than regular lay. Limited quantities of LHL laid were used for the head-ropes of seine nets. A single RHL headrope tended to kink or roll undesirably, because of its internal torque, and this could be neutralized by twinning it with a LHL hawser of similar size.[22]

18 The illustrations are from two anonymous articles, the chapter 'The Manufacture of Ropes and Cordage' in *The Useful Arts and Manufactures of Great Britain*. A concise contemporary account of the entire ropemaking procedure is found in *The Mechanic's Magazine,* vol. IX.

19 Luce, *Seamanship,* 34.

20 Burney, *Boy's Manual of Seamanship,* 90.

21 Ashley, *Book of Knots*, 23.

22 Ibid.

Figure 12 *Coiling RHL rope (Author's sketch)*

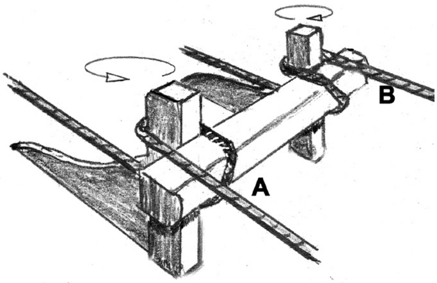

Figure 13 *Cable bitted (Author's sketch)*

Handling of fibre rope
Sailors were trained to coil RHL rope clockwise or 'with the sun', as shown in figure 12. This slightly loosens the lay, making it more pliant, and as each turn is taken, the tail end twirls anti-clockwise a full turn axially. Were the end kept fast, the rope would develop kinks. In some circumstances, for example in turning in deadeyes, pliancy was not important and the turn was made against the sun, to keep the lay as tight as possible, and resist the ingress of water. Experiment demonstrates that short lengths of loosely laid RHL can readily be coiled left-handed, but this is not the case with longer lengths of stiff rope.[23] The ultimate test of a 'properly' coiled rope is its ability to run easily through a block without kinking, as for instance a staysail halliard, when the sail is suddenly dropped.[24]

Since cables were cable-laid, it might be assumed that they were coiled down against the sun. In fact, there was substantial difference of

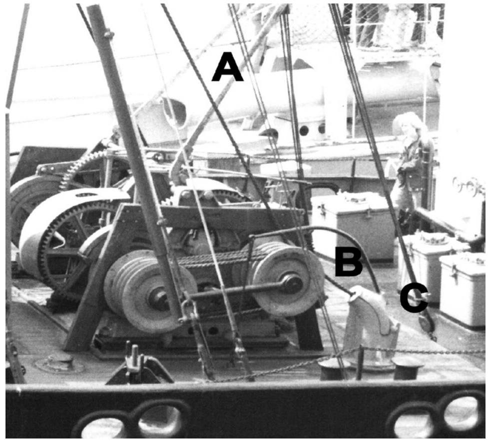

Figure 14 *Whaler RAU IX (Author's photo)*

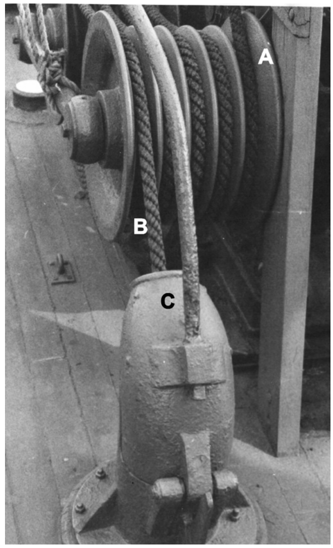

Figure 15 *Whaler RAU IX (Author's photo)*

opinion about this, with some contemporary authorities advising coiling down with the sun, and others championing 'coiling as bitted'. That is to say, the starboard cable was coiled down with the sun, and the port cable against it. Figure 13 shows how the cables were hitched round and cross-piece, or 'bitted'. The cable ran from forward, outside the bitt-post, under the cross-piece, and then diagonally upwards and inboard around the post, and led aft. This means that the port (A) and starboard (B) cables twist in opposite directions. I must admit it is not clear why this would have influenced how

23 Des Pawson pers. comm.
24 Frank Scott pers. comm.

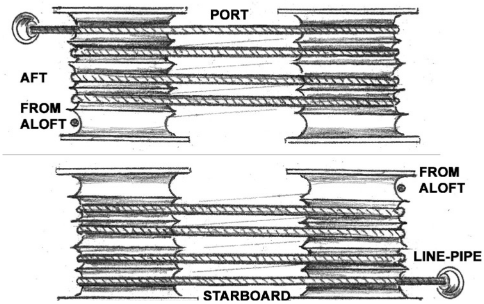

Figure 16 Double-drum winch (Author's sketch)

the cables were coiled in the tier, and perhaps it was no more than a traditional custom. In any case, the cable was not forced into a coil of small radius, but laid out in rectangular fashion in a fairly generous space, the dimensions of which were determined by the size of the platform in the orlop.[25]

The remarkable thing about the only length of LHL rope I ever saw was that it was being used in one of those extremely rare situations, where lay did matter, and where only RHL would have been correct.[26] The photos in figures 14 and 15 were taken 40 years ago, and show a traction-winch in a whalecatcher on view at the Deutsches Schiffahrtsmuseum, Bremerhaven.[27] The winch was designed to handle 6-inch manila whale-line, light enough to follow a harpoon in flight, yet strong enough to deal with a 50-ton whale. The line led down from a spring-block aloft, made four turns round the drums and led through a line-pipe down into the storage bins below deck (figure 16). The line-pipe was forward of the drums on the starboard side, aft of them on the port side, and this asymmetry reflected the fact that the whale-line, invariably RHL, was taken around the two drums clockwise in the same way RHL rope was coiled down clockwise. The background story behind the design of the whaling-winch is discussed elsewhere.[28]

25 Harland, *Seamanship*, 236.

26 Actually a small cable.

27 This rope has long since been removed. Ingo Heidbrink, pers. comm.

28 Harland, *Capstans and Windlasses*: chs 8 and 9; Harland, *Catchers and Corvettes*: ch. 18.

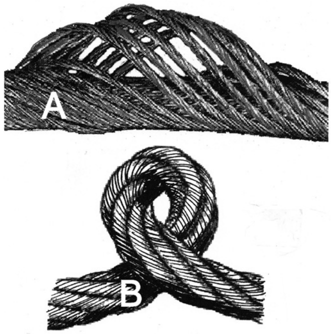

Figure 17 Birdcage and kink (Author's sketch)

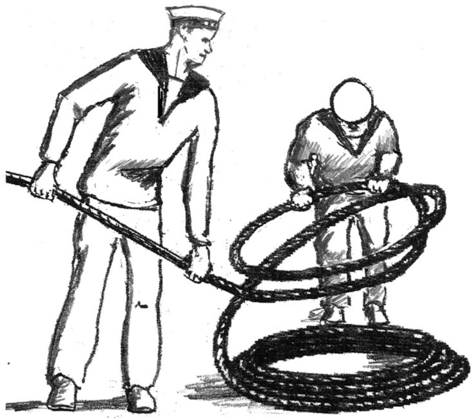

Figure 18 Taking a 'Frenchman' (Author's sketch)

Wire rope

Nowadays wire ropes of extremely sophisticated design are in wide use, but the earliest practical examples were developed by the German mining engineer Wilhelm August Albert in 1834.

Short lengths of wire can be coiled down temporarily on deck, but it needs more careful handling than its fibre counterpart, because if kinks or 'birdcages' develop, as in figure 17 (A) and (B), the whole length is effectively rendered useless. RHL wire is best coiled down clockwise, but should it have, here and there, a left-hand 'set', it will be necessary to take an occasional counterclockwise turn, or 'Frenchman', as in figure 18. However, for most purposes it is stored on reels, and although this could be done higgledy-piggledy, where greater

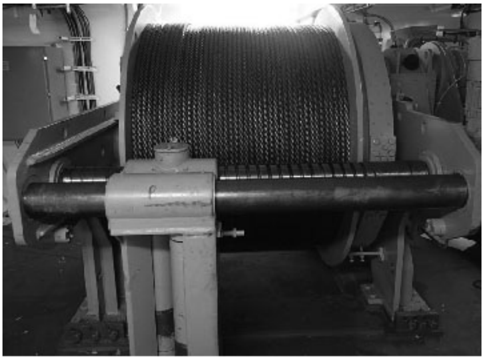

Figure 19 Wire rope neatly coiled on a drum (Photo courtesy RAPP Hydema, Bodø)

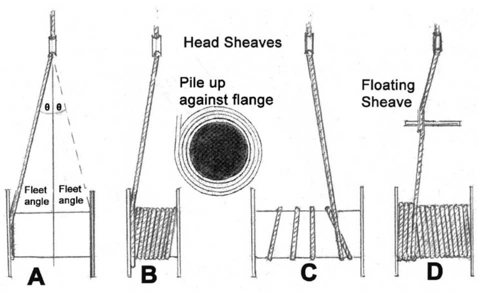

Figure 20 Fleet angle (Author's sketch)

lengths are involved, it is preferable by far to wind it on in neat layers as shown in figure 19.[29]

LHL is little used in the maritime applications, but very substantial quantities are sold to the mining industry, and since our topic is the lay, this is worth a paragraph. We will first consider the situation where the wire leads directly to the drum from a distant guide- or head-sheave direct as shown in figure 20A The angle subtended by a line from the sheave at right angles to the drum and one between sheave and side-flange is called the 'Fleet Angle'. This is determined by the width of the drum and the distance between sheave and drum. As determined by experience, this ratio should be 1:23, which corresponds to right and left fleet angles each 1° 20' or so. If the fleet angle is too small, the wire reaching the end of the layer, will be reluctant to part from the flange and the turns will 'pile up' as shown in figure 20B, whereas if

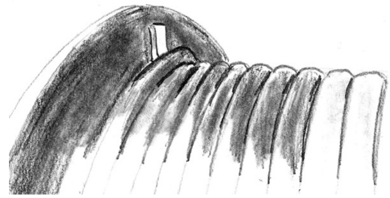

Figure 21 Kicker plate (Author's sketch)

the angle is too large, there will be gaps between the turns.[30] Various expedients are employed to obviate mis-spooling of the subsequent layers. The wire can be jogged away from the flange by a chamfered kicker or nudge-plate secured to the flange, as in figure 21,[31] or a 'floating sheave', or 'fleet angle compensator' can be interposed between head-sheave and drum, as in figure 20D. This can slide on a transverse axle, and the tension on the wire tends to shift it into the more favourable position abreast the drum. The ultimate solution is a spooling-guide, or level winder (figure 19) that traverses exactly one wire-diameter per turn, and reverses direction at the end of the run.

Lay of wire rope

In none of the above situations is the lay of the rope important, but this does become a significant consideration if the direction of rotation, that is to say whether the wire is being wound on to top or bottom of the drum, is taken into account. As it spools on, the wire tends to roll as if were trying to unlay, and therefore the direction in which the wire wants to move and the fix-point are determined by lay. The most convenient way of summarizing the various combinations is diagramatically as shown in figure 22.[32] A mnemonic based on this is the 'hand rule'.[33] Looking towards the head-sheave, and using the right hand for RHL, left hand for LHL wire, the index finger points towards

29 Photograph courtesy Rapp Hydema A/S, Bodø, Norway.

30 A video clip illustrating this can be found at www.youtube.com/watch?v=uwgFkACxgWc

31 Frank LeBus US Patent #2,620,996 (1952).

32 I am most grateful to Herr August Rich, Managing Director, Drahtseilwerk Dietz GmbH & Co. KG, Neustadt bei Coburg, for permission to use this figure.

33 Based on similar *aides-mémoires* long used by students of elementary electro-magnetism.

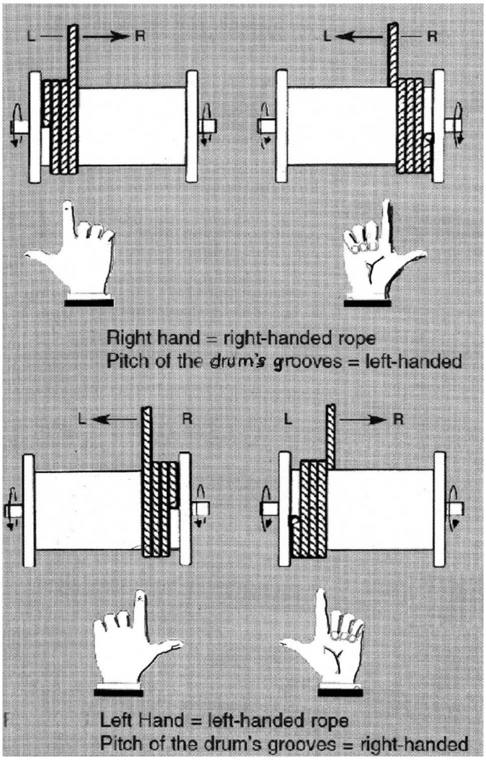

Figure 22 *'Hand rule' (Courtesy Drahtseilwerk Dietz)*

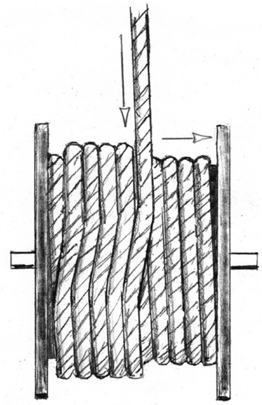

Figure 23 *Crossover (Author's sketch)*

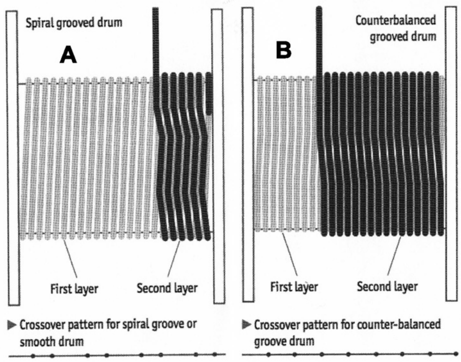

Figure 24 *Circumferential grooves. (Courtesy Dennis Fetter)*

the head-sheave, the curled fingers indicating whether the wire is under- or over-wound, and the thumb points in the direction the rope wants to move and hence the side of the fix point. It is clear that the words 'clockwise' and 'anti-clockwise' are next to useless here, because it all depends from which side the observation is made, and because unlike manual coiling down, it is the drum rather the wire that is doing the rotating. To put the diagram in a practical context, note that LHL wire rope is much less common than RHL, and minesweeping- and trawl-winches, those of primary interest in the maritime world, are always under-wound.

It must be emphasized that the hand rule applies only to the initial or ground layer of wire. If the end of the wire were secured at the left end of the drum, the turns spool on from left to right, and when the wire reaches the flange on the right, the turns reverse direction and the second layer is laid down from right to left. The wire is not being laid down circumferentially (parallel to the flanges) but rather in a series of shallow spirals, with the 'lead' or axial advance of each turn, being equal to the circumference of the wire.

It turns out that the 'rules' are rules in name only, with many exceptions in the practical world. If the wire in a particular layer is the 'working' part constantly being veered or reeled in, it will be best if that layer moves in accordance with the hand rule, rather than the ground-layer which is just 'dead-wrap'.

Crossovers and sophisticated grooving

Each wire lies in the depression between the turns of the layer below, but because the spirals are approaching each other and are of opposite sense, with each revolution of the drum there will be two crossover points, where the wire must 'jump' across the wire on the layer below, as in figure 23. Figure 24A makes

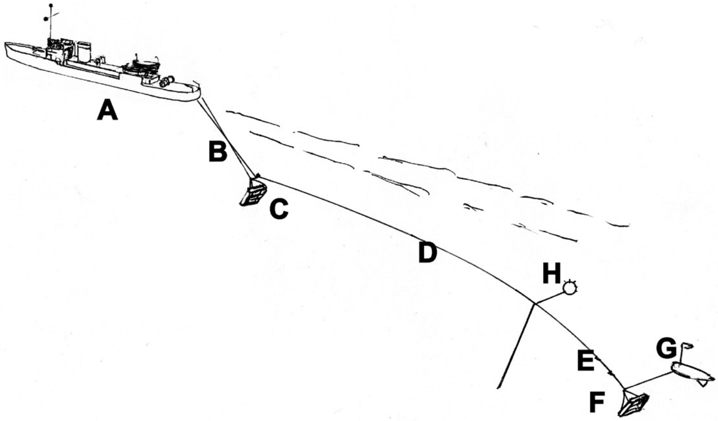

Figure 25 *Minesweeping (Author's sketch)*

it clear that the crossovers are not situated at equal intervals, but are separated by alternate short and long spaces.[34] Asymmetric placement of the crossovers is enough to throw a drum turning at high speed out of balance, and cause it to vibrate violently. By cutting the grooves in the drum circumferentially, at right angles to the axis of rotation, and joggling them as shown in figure 24B succeeding crossovers can be induced to occur 180° out of phase with each other, keeping the drum in balance and eliminating pulsation.[35] These considerations only apply where the drum is rotating rapidly, as for instance when reeling in a wire line used to clear debris in the casing of the bore-hole of an oil well. The wire-reels used in the naval and maritime world, for example minesweeping and trawl-winches, are of greater diameter and slower speed than the oil-field and offshore machinery discussed above, and the vibration problems discussed above are of theoretical rather than practical interest.

Hydrodynamic aspect of lay of wire rope

Another situation where the lay becomes significant is when the wire is being dragged through water. Most wire rope is RHL, and my first encounter with the LHL variety occurred in 1943 when serving aboard the fleetsweeper *Pangbourne*. At this time, the ship was engaged in clearing moored contact mines in the Irish Sea, using the 'O' or Oropesa method.[36] Figure 25 shows a sweeper (A) with an *Oropesa float* (B), 700 fathoms of sweepwire (C) deployed on the port side, and swung outwards from the ship's wake by a multiplane *otter* (D), and held to desired depth by a multiplane kite (E).

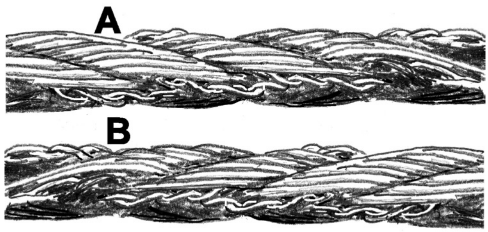

Figure 26 *Sweep wire (Author's sketch)*

Sweep wire was 2.125 inches in diameter and constructed of four strands round a rope heart. Additionally two single wires twisted together were laid along each strand as shown in figure 26, which roughened or serrated the surface giving the wire its ability to saw through the mine mooring-cable (F) and cause the mine (G) to pop to the surface, where it could be

34 I am most grateful to Dennis Fetter, Technical Director of WireCo World Group, Kansas City, for permission to use these explanatory diagrams.

35 Frank LeBus. US Patent #3,150,844, (1964).

36 The First World War trawler, aboard which boffins from HMS *Vernon*, worked out the technical nuts and bolts of O-sweeping in 1917, was called *Oropesa*.

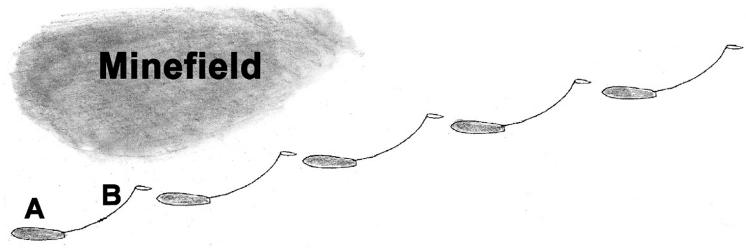

Figure 27 *An O-sweep (Author's sketch)*

destroyed by gunfire.[37] To clear a minefield, the sweepers (A) approached it in echelon, each ship following in the safe(!) swept path of its predecessor, as seen in figure 27, each clearing a swath about 900 feet wide. Having made a successful pass, the flotilla came back on a reciprocal path with the gear deployed on the other side. Back and forth they went, until the entire field had been swept, more or less like mowing a lawn. To maximize the breadth of sweep, the otter must pull the wire as far out as possible on the quarter, and to keep the sweep-wire at the desired depth, the wire must sag as little as possible. Both aims were achieved by using LHL lay rope to port, and RHL to starboard. I am sure my shipmates never thought of it in such complicated terms, but one way of explaining why this was done, is to invoke the 'Magnus Effect'.[38]

A simple way of explaining this is to consider what happens when spin is imparted to a golf ball, with the air through which it flies considered as a fluid. In figure 28A the ball has been hit in such a way as to give it backspin. The air entrained by the top of the ball moves in same direction as the airflow, and hence faster than the air entrained underneath the ball. Because of the inverse relationship of flow and pressure, (Bernoulli's principle), the pressure is less on top than below, a force at right angles to direction of travel is generated due to the additive and subtractive effects on opposing surfaces. In this case it is 'lift', causing

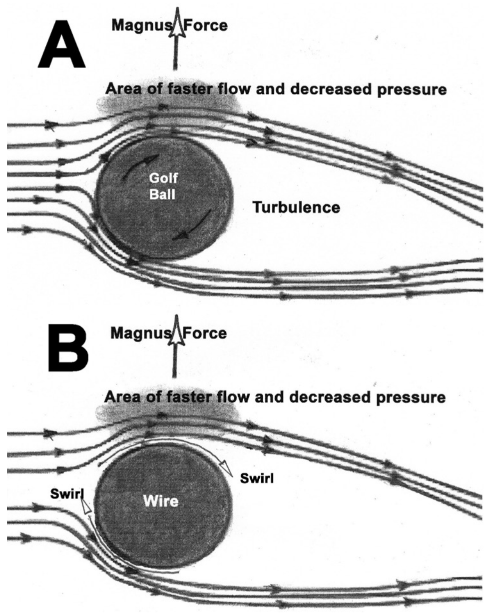

Figure 28 *Magnus effect (Author's sketch)*

the ball to travel further than if it had been hit squarely.[39] We can use a very similar diagram for the sweepwire, figure 28B, postulating that the lay of the rope causes the water in the boundary layer to swirl round the wire following the twist of the strands. Strictly speaking were the wire truly vertical or truly horizontal there would be no swirl, but since it is angling out and down, the boundary layer flow can be resolved into vertical and horizontal components and, in the

37 The neuro-surgeon's Gigli saw works on the same principle.

38 Heinrich Gustav Magnus (1802–70).

39 If the ball has topspin, it will tend to drop; if it has been hit on the right side, it will tend to *hook*, or go to the player's left; hit on its left side, I will bend to *slice* or go to player's right.

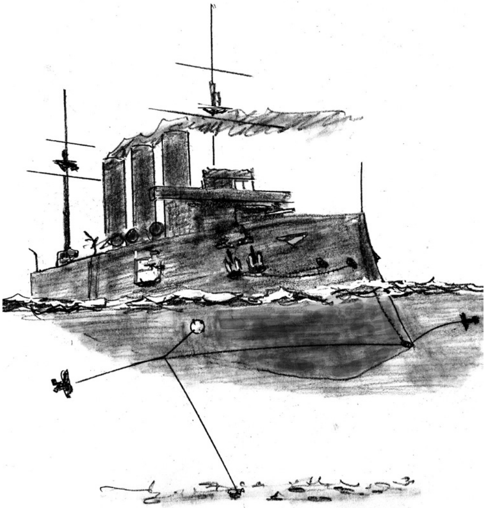

Figure 29 Paravane (Author's sketch)

case of RHL wire, the water would swirl in a clockwise direction, as viewed from the ship's stern, meaning that flow is faster on the forward and starboard side of the wire, generating a thrust that pulls it to starboard, augmenting the effect of the otter. If we consider the wire being towed horizontally, the faster flow on the upper surface of the wire generates an upward 'lift', tending to prevent sag and straighten out the downward curve of the wire between the kite and otter. Similar reasoning can be applied to the port sweep with its LHL laid wire. The length of wire that angles down is much shorter than the length that is horizontal, suggesting that the second of these effects is predominant. Kriegsmarine minesweeping techniques were rather different, but they did use LHL wire.[40]

A second mine-warfare measure used more in the First World War than the Second World War, was the streaming of otters (paravanes), when a vessel was in mine-infested waters. The underlying concept was that a submerged mine would be pushed aside by the pressure of a vessel's bow wave, but it was all too likely to be sucked in against the ship's hull further aft (Bernoulli's effect again), as shown in figure 29. Paravane otters (A) were streamed from the forefoot, raised and lowered by chains (B). Serrated wires were designed to cut the mine-cable allowing the mine (C) to surface at a safe distance from the hull. They were much shorter than those used with the Oropesa float, just over 200 feet in length, and a 1951 reference claims towlines of both lays were employed, with RHL being used on the port side … the precise opposite of what one would have expected.[41] We were also able to confirm that a few Scottish trawlermen, use port side LHL trawl-warps to improve the spread the otter-boards of midwater or pelagic trawl nets.[42]

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40 'Deutsche Minensuchgeräte' at www.ship-model-today.de/sd130.htm.

41 *Admiralty Manual of Seamanship* vol. II, 89, 435; Cornford, *The Paravane Adventure*, 252.

42 I am particularly indebted for information on this point, to Mike Montgomerie, Simon Dixon, Linda Fitzpatrick and Trevor Kenchington.

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