The climbing eased off after this but a short holdless corner gave a strenuous mantelshelf. The route was not finished yet, however. I received more cardiac exercise and a 6m fall when all my nightmares came true at the glimpse of a long scaly green body on a ledge which, too late I realized, had legs. This is the crux of any expedition here, to this author, for I unashamedly admit to being snakophobic (with some cause as snakes are very common) and never go even to the garage without my little red box of faith, 'Fitzsimmons Vintage Serum'.

Upon my return to the high point recently vacated, the monitor (for such it proved to be) about 3ft long, did not move a muscle, but the hornets whose hole he was watching attacked the hand (mine) that jammed itself in there, nearly precipitating another departure on my part, but I employed the insecticide to great effect once more and finished the route rapidly with some delightful bridging. We called the route Doom, as that was the name of the insecticide, and it seemed somehow appropriate!

The whole proceedings had been observed with incomprehension by a local elder who, having informed us that we should walk up around the back, sat down to watch the fools at play and within half an hour was telling us that we were climbing the wrong crack! He declined however, our offer to follow.

So who is insane? Since completing this article the pace has quickened with the arrival of another accessible climber—Roger Frerey. Routes are now being put up at one or 2 a week, including additions on Lovers' Rock and the opening up of some new cliffs around Lentswe-le-Tau. I will be happy to provide full details on request to anybody else who is interested in visiting the area.

Mountaineering ropes

Brian J. Dunn C. Eng., M.I. Mech. E., F.I. Plant E.*

The invention and development of man-made fibres

The concept of a man-made fibre is not new. Robert Hooke FRS in his book '*Micrographia*' published in 1665[3] postulated such a fibre. Insects such as the silkworm and spiders naturally perform an extrusion process. Indeed the spider carries the analogy even further, since it can produce different silks to perform specific functions. The synthetic fibre industry has learned to produce fibres with similar characteristics, but has yet to match the spider in producing such a range from a set of common amino acids.

Clearly, although the theory was propounded by Robert Hooke et al., the practice could not be realized with the technology then available. Imitation of the fibres found in nature was beyond the reach of man until the scientific and industrial developments of the 19th Century. Even then, the chemical knowledge did not permit the synthesis of man-made fibre materials, and so these early attempts turned on making fibres from converted natural products. These first fibres were obtained by dissolving natural cellulose and creating the fibre by extruding the dissolved cellulose into a coagulating bath where it reformed itself into a fibre.

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17 Viking Rope makes mountaineering history (Photo: Bridon Ltd collection)

A Frenchman, Chardonnet, commenced making artificial silk fibres on a commercial scale in 1885. The material was very inflammable. Several developments followed, the most notable being that of Cross and Bevan who invented the viscose rayon process (1891) and the cellulose acetate process (1894).

During the early years of the present century scientists did begin to acquire the basic knowledge and develop the techniques which enabled them to investigate the molecular structures of the more complex natural products, a labour still very far from complete. Also, the infant plastics and synthetic rubber industries were growing. The work of academic and industrial chemists and physicists on the structure and synthesis of plastics materials, coupled with the investigation of natural rubber, of cellulose, and of wool, silk and other proteins, brought about the gradual realization that the molecules of such materials are composed of many thousands of atoms joined together by chemical bonds.

The concept of the macromolecule marks an important step in the development of chemistry. In common with most advances in science, as in all areas of human activity, many people contributed both work and thought over several years, but H. Staudinger was the first to propose clearly synthetic polymeric structures (1920) and to provide logical experimental evidence in support of them. Universal acceptance by chemists was delayed to the 1930s for various historical reasons (scientists in general may be as reluctant to accept new ideas as anyone else) and more cogently because there was little convincing experimental proof.

The fact that natural macromolecules are built up from small basic units pointed the way to laboratory methods of making novel, synthetic polymers, first by making the units—the monomer—and then by coupling them together, both stages being possible by methods known in classical organic chemistry. Outstanding in the realization and early exploitation of this important principle was W. H. Carothers, who worked for the Du Pont Company (USA) from 1928 onwards, and produced the synthetic fibre nylon (and other important polymers) which was first marketed in 1938.

Once the principles of polymer structure and synthesis were established, and with the production of the first plastics, synthetic rubbers and synthetic fibres, the foundations were laid by the late 1940s for the rapid rise of giant industries, and for an upsurge of basic and applied research work in the new Polymer Science. This growth is by no means ended.

The availability of nylon multifilament and the subsequent addition to the man-made fibres range of polyester, polyethylene, polypropylene and aramide fibres have revolutionized cordage technology. The four latter fibres are, however, beyond the scope of this paper.

Concepts of measurement

Apart from well understood and defined parameters such as breaking strength and mass/unit length, it is not possible always to apply the practices of measurement commonly used for metallic items to textile fibres. Instead of describing a man-made fibre yarn in terms of the number of filaments and the nominal filament diameter, it is more usual to quote the linear density in tex units. The 'tex' of a yarn is the mass in grams of one kilometre of the yarn. Hence, a nylon yarn of 1680 tex will weigh 1.68kg/km or 1.68g/m (and will also contain over 1500 filaments).

It will be realized that the problem of determining with any accuracy the cross sectional area of such a large number of filaments which are not all of the same size would be considerable. This problem is compounded by the high elongation exhibited by these yarns before failure. A yarn having an ultimate extension of 25% would be expected to reduce in diameter by 5% during the tensile test. Furthermore, load is not directly proportional to extension and thus a stress based system clearly is impractical.

The alternative is to use a system based on the mass/unit length of the yarn, and to compare the breaking strength with this. This term is called 'tenacity' and is expressed usually in grams/tex (or more properly N/tex). As in other SI units, multiples and submultiples of these values are permitted.

It is also useful to be able to measure the amount of energy which a rope can absorb or reject during its loading and unloading cycles. These values can be obtained quite easily for example by means of a planimeter, or by Simpson's Law or even the counting of squares once the relevant load/extension curves and hysteresis loops have been drawn.

The unit of breaking strength, for traditional reasons, is expressed in kilograms or tonnes. Strictly speaking, this is incorrect and a newton unit should be used. Besides being technically accurate, this also has the advantage that the energy absorption values discussed above may be more simply calculated in terms of J/m or J/g than the more usual m.kp/m. This latter unit always confuses the metres and 'milli' symbols and makes the precise unit unclear.

Until fairly recently, the breaking strength was the primary consideration. Latterly, this parameter has tended to be considered only as of secondary importance. If strength were the only attribute, it would be a simple matter for the ropemaker to make a rope sufficiently strong. The fact that the climber might have difficulty carrying it, or that the low elongation under load would create high shock forces on his body when he fell on it, causing him physical injury, cannot be ignored by the ropemaker. Hence, a rope is required which is light, and strong enough for the purpose, but also with sufficient extension to reduce the forces on the body being arrested to an acceptable level. Thus the concept of 'peak force' has been introduced. This represents the maximum transmitted force which occurs when a known mass falling through a known height impacts the end of a known length of rope which is anchored at its other end.

Mountaineering ropes[4] awarded the Label by the Union of International Alpine Associations are subjected on a sample basis, to a practical drop test.

Single ropes

The sample under test has to withstand a minimum of 3 drops of an 80kg weight on a free fall of 5m on 2.5m of free rope (approx. fall factor 2; see below). Both the weight and the fixed end of the rope are attached by a bowline knot. The rope passes through an orifice in a fixed plate at half the height of the fall (in effect this is 0.3m from the fixed point); the orifice in the plate has a radius edge of 5mm simulating the edge load produced by a karabiner. The maximum impact force is recorded during the test and must not exceed 1200kp for the test to be successful.

Double ropes

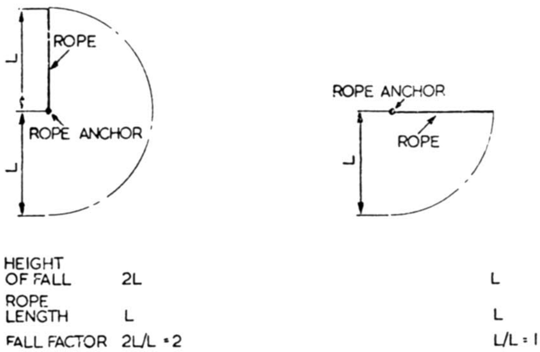
As above but the falling weight is reduced to 40kg and the Impact Force must not exceed 600kp.

(Note. As from July 1977 Double Ropes will be tested as a 'double strand' on 80kg mass with a recorded value of impact force not to exceed 1200kp. However, manufacturers are allowed for a period, to a maximum of 18 months, to use the previous method. Some ropes currently being offered may relate to the earlier specification.)

A further consideration peculiar to climbing ropes is that of fall factor. The fall factor is the ratio of the length of the fall to the amount of rope available to absorb the energy of the fall. Examples are shown below.

The ropes

There is no question that the most important technological development in mountaineering occurred with the transition from Italian hemp to nylon as the



18 Fall factors (This and next 2 figures: Bridon Ltd)

material from which the climbers' ropes were made. Before the advent of man-made fibres, there is no question that the high strength and uniformity of a well spun Italian hemp yarn produced a rope having properties unequalled by any other natural fibre. It was not without disadvantages, however. It would rot if it was stored badly. It would stiffen when wet, and it had the low extension under load associated with all natural fibres. Hence, the arrestation of a falling leader was very abrupt, and the shock loading transmitted to the second man was also correspondingly high. With the longer pitches being climbed in those days, it is surprising that more climbers were not pulled off the face by a falling leader.

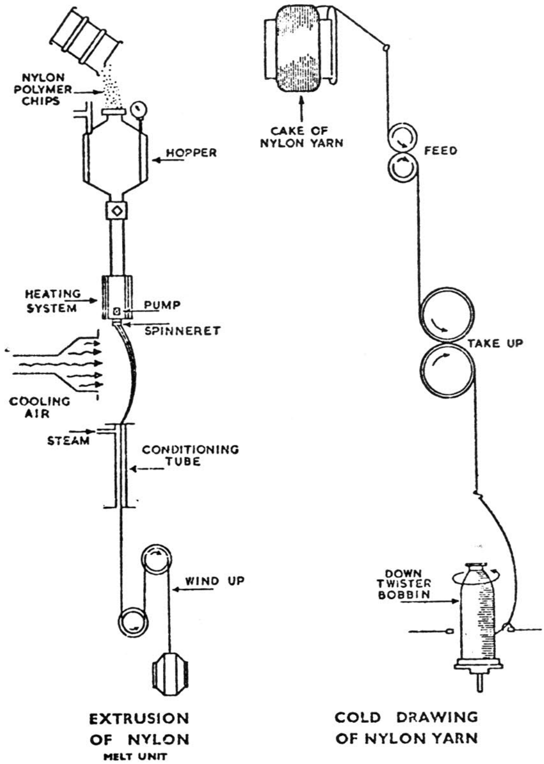
The modern mountaineer has to trust his rope implicitly. Provided that he has made a correct choice of size and has chosen a rope which was made either in accordance with British Standard 3104, or has the UIAA certificate, then he has a guarantee that the ropemaker has done everything possible to make his climbing safe, by providing a product specifically designed for the application. The climber who seeks to save money by buying normal industrial quality rope or government surplus can have no high regard for his personal safety, nor much regard for that of the rescue services who will have to be called out in the event of an accident.

The basic component of the modern mountaineering rope is a nylon filament. This is a single fibre, continuous, of circular cross section, and 25μm–40μm (0.001–0.0015in) in diameter. The term 'continuous' may be taken literally. It is quite feasible, theoretically, to follow the path of a single filament through several miles of cordage without any break or discontinuity being observed.

Manufacture of the ropes

A cluster of such yarns are collected together by the producer and wound on to a cylinder. In this form they are known as 'base yarn'.

The techniques involved in converting this base yarn into rope are well established and the principles have been used for many thousands of years. Examples of ropemaking have been found in Egyptian tombs dating from 3500 BC. Whilst the principles have remained, they have been refined quite satisfactorily in terms of the materials which are used in cordage manufacture. The early Egyptian ropes were made from material such as alfalfa, camel hair, flax and date palm fibre. The Greeks and Romans used flax, hemp and esparto grass. Hemps and flax were used extensively from the middle ages until the middle of the 19th Century. Coir



19 Extrusion and cold drawing of nylon

rope was used to launch the 'Great Eastern' steamship built by I. K. Brunel on the Thames in 1858. Towards the turn of the 19th Century manila fibre made an appearance and quickly made inroads into the soft hemp markets. Manila itself, although still a commonly available cordage material, yielded pride of place during the Second World War to sisal. Whilst the properties of both these fibres were inferior to high grade Italian hemp, they were acceptable for most applications. The fibres were also much cheaper and it made good economic sense to use them.

Nylon (and other man-made fibres ignored for the purpose of this article) have become available since the end of the Second World War. The properties of nylon were so far in advance of comparable natural fibres, that it became an immediate choice for mountaineering ropes. Initially, a traditional 3 strand construction was chosen but for the last 15 years or so, this construction has received competition from plaited ropes. Both have a place in the field, and both are still commonly available.

Three strand mountaineering ropes are made from high tenacity nylon yarn and have a tenacity of not less than 705mN/tex (72g/tex).

It should be emphasized that the description of the manufacturing processes which follow are those followed by the author's company and represent good practice. They should not be regarded as being universal. Other ropemakers may use variations of this technique, but the general processes would be similar.

The base yarn must be of a fine count in order that the finished rope complies with the specified requirements and is of good appearance. Each batch of yarn received from the yarn manufacturer is carefully tested to ensure that all the physical properties necessary for this exacting type of rope fall within the close limits set by the inspection department, and only after passing this quality control does the yarn proceed to the production department for processing.

When the fine count base yarn has been accepted and passed by the inspection department, it is then twisted into rope yarns on modern precision twisting machines. The utmost care is taken at this stage to ensure that tensions are uniform, the twist factor is constant and the final rope yarn is free from contamination by oil, grease or dirt. Lubricating oils and greases are harmless to the strength of the yarn, but cause unsightly staining, which would result in rejection by inspection.

Inspection at this stage ensures that the twist factor is correct and that the correct number of base yarns has been twisted together. At the time of inspection the rope yarn runnage is checked for accuracy.

The rope yarns are then assembled on the bobbin bank of a stranding machine, accurately circled through holes in a register plate, and twisted through a tubular die into rope strand. The direction of twist of the strands is the reverse of the direction of the rope yarn twist, and the directions are right hand for the rope yarns and left hand for the strands.

Inspection at this stage ensures that the correct number of the approved rope yarns are incorporated, and that the rope yarn circling is correct. The inspector also measures the strand lay and visually examines the strand for freedom from proud or sunken yarns.

Next 3 bobbins of the finished rope strands are assembled into the creel (or basket) of the rope making machine and twisted into rope, which is right-hand hawser laid. At this stage, inspection ensures that the rope is well formed.

After manufacture, the rope is heat treated at a temperature not less than 115°C to set the lay and ensure dimensional stability. The rope is inspected again at this stage to ensure that time, temperature and tension are correct during the heat treatment operation.

The rope is now finished, and may now be made ready for the customer. The long length is taken from the machine and laid out on a long table where it is subjected to a visual inspection. After this inspection the rope is cut into the specified lengths required by the customer and each end of each length is palm and needle whipped for a distance of 25mm. The rope ends are heat sealed which prevents the rope becoming unravelled should the whipping be lost.

The made up lengths are then hanked, labelled with the manufacturer's name, specification number and, possibly, the rope number before being packed into an individual protective carton.

Samples from the rope are selected at the inspection and cutting table, and after conditioning are subjected to tests in the physical laboratory to ensure that rope of the correct quality has been produced.

Ropes made by this process must satisfy the requirements of British Standard 3104 (Nylon Mountaineering Ropes). Four sizes are stipulated. The 2 smallest sizes are primarily for climbing slings etc. The 10mm diameter rope may be used double for climbing, and the 11mm diameter rope is designed to be used as a single climbing rope.

Plaited ropes (kernmantel) have become a common feature of mountain equipment. The sheath must provide an adequate abrasion resistance as well as contributing some strength to the final rope. Consequently, machines have to be used to provide a sheath comprising a large number of braids which give a firm, fine, and smooth sheath structure. The sheath is normally dyed in attractive colours before braiding commences both to enhance the appearance of the rope cosmetically, and also to protect the rope from the ultraviolet radiation present in sunlight, which tends to become more intense with increasing altitude and thinning atmosphere.

The use of luminous dyes has opened up entirely new possibilities, even though the very high lightfastness requirements cannot be fully met and the available colour range is still rather limited.

Today, for most types of fibre, the basic dyeing problems can be regarded as solved. However, this does not exclude the possibility that when different fibre types are used, special questions may arise which often call for extensive preliminary trials.

A great advantage of braided ropes is the absence of spin on loading. If a twisted rope is loaded in an axial direction torsional strains are created due to the twist angle, and the rope tends to unwind itself. With a braided rope, however, these forces cancel each other out.

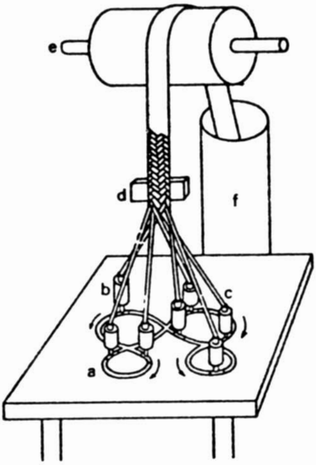
A braiding machine can be described in simple terms as an assembly, known as a deck, of 2 flat metal plates bolted together with a train of horngears between them. The gears are arranged to propel the spool carriers round a double track which is cut in the upper plate to form a succession of figures of eight. The yarns coming off the moving spools meet at the 'braiding point' on a centrally mounted former, and the finished braid is drawn off continuously at a uniform rate by a roller connected to a change gear system. It is then delivered into a can or wound on to a drum. For tubular braid the track completes a circle round the braiding point, and the path traced by the carriers is exactly similar to that of the dancers round a maypole, who are in fact 'braiding' their ribbons on the pole.

Maypole braiders are built either on the carried carrier system, in which the carriers actually ride on the horngears; or on the slide plate or Barmen system in which the carriers sit on the track plate, and the horngears simply propel them round the track. The disadvantages of the slide plate system, such as higher energy consumption, the need for more frequent lubrication, heavy surface wear and more noise, may have been largely overcome by the development of moulded plastic gears and carriers.

As the carriers travel round the track they are moving radially in and out so that the distance from any one spool head to the braiding point is constantly changing. It is a function of the carrier, as it pays out the thread, to keep it under constant tension. On the older type of carrier this is done by means of a simple drop weight, either an external weight or one enclosed in the tube on which the bobbin sits. As it slides up and down the carrier stem according to the distance of the carrier from the braiding point, the weight activates a supply release pawl or 'dropper', which engages in a ratchet on the bobbin head. Modern braiders have spring tension carriers, which make higher running speeds possible.

Braid sizes and types are determined by the number of carriers and by the horngear 'pitch', which is the distance (in mm) between the axes of a pair of horngears, and is thus governed by the diameter of the gear; the wider the gear the bigger the yarn package it can accommodate. Unfortunately there are as yet no recognized standards for pitch.

It is widely believed—and falsely—that in core-sheath ropes only the core



20 Braiding machine

a track plate
b spool carrier
c braiding yarn
d braiding point and former
e take off roll with change gears
f delivery can

performs an actual load-bearing function. In fact, core and sheath are so closely involved one with the other as a result of the structure of the rope that a separation of load-bearing functions is impossible. However, one special property that the sheath must possess is a very high resistance to abrasion. This is achieved amongst other things by using machines with a large number of spools, which give a firm but fine sheath structure.

Ropes for other mountaineering applications are also made in this way. Mountain rescue lines, made from polyester fibre to specification UK/AID/962 also have plaited sheaths. These ropes embody a parallel core since a low extension under load is required.

This article has attempted to give the reader an impression of the history and the present position with respect to mountaineering ropes. New materials and new constructions will be developed and the ropemaker will certainly play his part in making the mountain as safe as possible for the climber.

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