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The Lubrication Of Yarns For Weft Knitting

(Study Report)

by

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Introduction

In general, all knitting yarns are lubricated at some stage during their manufacture to aid processing. This applies whether the yarns are natural or synthetic, staple or continuous filament and regardless of the method of fabric manufacture to be used. With yarns destined for the weft knitting industry, however, adequate lubrication at the winding stage immediately before knitting is, in the majority, essential if trouble-free knitting, fabric quality, maximum yield and machine flexibility is to be obtained and maintained during fabric production.

1. Reasons for Lubrication

Friction

The main reason for lubricating a yarn prior to knitting is to reduce its frictional properties to the lowest possible level. This is necessary because, on the knitting machine, the yarn is required to pass over a large number of different surfaces and the friction between the yarn and any surface it passes over manifests itself as a tension generated in the moving yarn. Although a certain amount of tension is acceptable and indeed necessary in order to control the yarn's movement, if the tension generated becomes too great, it can seriously affect knitting. For example:

- In extreme cases, where tensions are induced in excess of the tensile strength of the yarn being knitted, the yarn will break.
- In less extreme cases, the extra effort required by the knitting elements in an attempt to overcome high tensions will result in miss-knitting and a very high percentage of faults in the fabric.
- In all cases, where yarn is knitted without positive feed control, tension directly affects course length. This in turn affects fabric appearance, dimensions and yield.

Unfortunately, the effect of friction on tension is cumulative. This fact is illustrated in *Tables 1 & 2*, which have been calculated from an equation which relates the ratio of output tension and input tension to the coefficient of friction of the yarn.

$$To / Ti = e^{\mu\theta}$$

Where	To	is output tension
	e	is the base of the natural logarithms
	Ti	is input tension
	μ	is the coefficient of friction
	θ	is the angle through which the yarn wraps at the friction surface.

The generation of tension in a yarn on a knitting machine is dependent on four variables:

1. The frictional properties of the yarn;
2. The number of surfaces the yarn passes over;
3. The frictional properties of the surfaces;
4. The angle at which the yarn passes over the surfaces i.e. the angle of wrap.

Therefore, to maintain yarn tension at an acceptable level for knitting, the effect of these four variables on yarn tension must be controlled.

For example, tensions generated between the supply package and the needles can be reduced by avoiding large changes of direction and by keeping the number of yarn/solid contacts to a minimum, also by ensuring that the surfaces over which the yarn must pass have low frictional coefficients. This will create some reduction and control of tension as far as the needles. However, once the yarn enters the knitting zone, the path of the yarn, the number of contacts and the angles of wrap are, to a large extent predetermined and cannot be reduced. Consequently, the coefficient of friction of the yarn must be kept as low as possible to avoid excessive tensions building up during loop formation. This point is illustrated in *Table 2,* where a change made in the coefficient of friction reduced the theoretical tension in the yarn from 6,000 g to 173 g.

Although it is apparent that yarn lubrication prior to knitting is very important, it would not be true to say that unlubricated yarns cannot be knitted successfully. In certain circumstances, for example where the construction is simple and the structure relatively slack, unlubricated yarns knit very well. However, as structures become tighter and more complex the frictional properties of the yarn become more critical and it is under these conditions when optimum lubrication can make the difference between good knitting and no knitting at all.

Although the main reason for applying a lubricant to the yarn prior to knitting is to reduce the coefficient of friction, lubrication also has other advantages which directly assist the knitting process.

Fly

One of the major problems encountered when knitting staple yarns is the amount of fly which is produced. Effective control of fly is necessary because excessive fly production can hinder efficient knitting by clogging the knitting elements, feeder eyes, stop motions etc. and impair fabric quality by causing an increase in fabric faults and uneven loop formation. In addition, the atmospheric pollution makes very unpleasant working conditions. The addition of a lubricant to the yarn reduces fly production considerably, as can be seen in *Fig. 1*.

Static

Another problem which can be overcome by lubrication is the excessive build up of static electricity during the knitting of continuous filament and staple synthetic yarns. When the static charges become strong enough, they cause the individual fibres and filaments of the synthetic yarns to mutually repulse each other. In staple yarns, this can result in an increase in fly production and all the problems connected with it. In continuous filament yarns, static can cause ballooning of the individual filaments. If ballooning occurs, the yarn becomes very vulnerable to damage, the individual filaments get caught and broken in the knitting elements and therefore, fabric quality is affected. Lubrication of the yarn prior to knitting, can, to a large extent, overcome and control the build-up of static and, in addition, special anti-static agents can be included in the lubricant to provide stronger control when necessary.

2. Types of Lubricants Available

It would be impractical to give a detailed and comprehensive list of all the various types of lubricants available to the winder because (a) the ranges are so extensive and cover every requirement of yarn and machinery that would normally be wanted and (b) because not all producers publish lists of their product range. However, some indication in general terms can be made.

Yarn lubricants can be divided into three groups, namely *Solid Waxes*, *Emulsions*, and *Coning Oils*.

Although each group generally relates to a particular type of yarn, e.g. solid waxes for staple yarns; oils for continuous filament yarns, a certain amount of overlap in the case of emulsions and oils is found.

Solid Waxes

Solid waxes are used in the majority of machines winding staple yarns. The main ingredient for a solid lubricant is fully refined paraffin wax, either on its own or with additives, e.g. tallow, spermoil, silicones, emulsifiers etc. The additives are included to change or complement the characteristics of the pure wax to a greater or lesser extent, for example, melting point, hardness, penetration, ease of removal etc. In addition, other solid lubricants can be made from polyethylene glycols or refined from crude petroleum.

The following are just some of the solid waxes available, although their relative merits as lubricants are not discussed.

Paraffin wax	Fully refined paraffin waxes of various melting points.
Silicone 2½ % Silicone 5%	Paraffin wax + silicones. The percentages given are nominal only.
SKO	Paraffin wax + silicones and oil, the amounts are not specified.
Spermex	Paraffin wax + spermoil.
Wax Tallow	A mixture of paraffin wax and tallow.
DEV 169	Composition not known.
PEG 4000 PEG 1500 PEG 1000	Polyethylene glycols. Numbers are the average molecular weights.
Shell Microwax	A mineral wax with a fine crystal structure derived from crude petroleum.
Nox	A mixture of paraffin wax and Nopco 1100R.
Estol 120 and 405	Commercial waxy esters.
DMS	Dimethyl stearamide.
Span 40	Sorbitan monopalmitate.
Span 60	Sorbitan monostearate.
Theobromo oil	Solid fat obtained from cacao.
Slack wax	A mixture of crystalline and microcrystalline waxes containing varying amounts of oil.

Emulsions

Emulsion lubricants can be used for either staple or continuous filament yarns although, due to some of the problems that can arise during application, they have not been so popular in recent years. The following are some commercially available emulsions.

SMP emulsion	Sorbitan monopalmitate emulsified with phosphate ester.
MO emulsion	Mineral oil emulsified with phosphate ester.
BS emulsion	Butyl stearate emulsified with phosphate ester.
Mulsine HF	A self-emulsifying mineral oil.
Waxemul	Paraffin wax emulsion.

Coning Oils

Coning oils, so called because they are applied during cone winding, are used almost exclusively for lubricating continuous filament yarns, although there are instances where staple yarns are oiled prior to lubrication with a solid wax. Yarn lubricating oils can be obtained from a variety of sources, although mineral oils are probably the most popular from the point of view of lubricating efficiency and cost.

Mineral Oils

Coning oil is manufactured from white or pale-coloured refined mineral oil compounded with anti-static agents, anti-oxidants, emulsifying agents and corrosion inhibitors, also a small percentage of water, about 0.5%, which acts as a stabiliser and clarifier for the other additives.

Vegetable and Animal Oils

Vegetable oils, especially olive and castor oils, have been used for continuous filament yarn lubrication. They are, however, very expensive and not particularly good lubricants.

Animal oils, such as Neatsfoot oil and lard oil have quite good lubricating properties, but the smell is considered objectionable.

Fish oils and whale oils are generally unsuitable as lubricants as they tend to oxidise, but sperm oil, from the sperm whale, which shows no such tendency, is a very good lubricant for continuous filament yarns.

Unfortunately, it is very expensive and, consequently, it is very unusual to find it used on its own today.

Synthetic Oils

Synthetic or partially synthetic oils are used to some extent as yarn lubricants. They consist usually of esters of high molecular weight alcohols and fatty acids and they are compounded with additives similar to mineral oils. One advantage of synthetic oils is their good oxidation resistance.

Emulsifying agents and similar compounds

The presence of emulsifying agents in a mineral oil can greatly enhance its lubricating properties. Emulsifying agents and other surface active agents, such as soaps, synthetic detergents and textile softeners have all been used as lubricants with varying degrees of success. Their main advantage is that they are water soluble and act as detergents during scouring or, if a scour is not carried out, they can, in some cases, assist in dyeing. Unfortunately, they are very expensive, and this outweighs any advantages they may have over more conventional lubricants.

Polyethylenes

Low molecular weight polyethylene compounds, either alone or in an aqueous solution can be used as lubricants. However, although their lubrication effect is good and they are water miscible, they are again very expensive.

Silicones

Silicones are often applied as a solution in mineral oil with the usual additives. However, they do not appear to offer any major improvements to lubrication. Pure silicone oils also have no advantage over mineral oils in lowering yarn/metal friction; they are difficult to scour after processing and their cost is very high.

Special Lubricants for Specific Problems

On occasions, a specially modified or formulated lubricant is necessary to perform a more specialised job or to overcome a particular problem. When this is so, most of the major producers are willing to help in its development and have technical research and development facilities available to offer this service. One such example of manufacturer's co-operation was the development of the Shirley UVI Fluorescent Wax.

Shirley UVI Fluorescent Wax

The Shirley UVI Fluorescent was developed in conjunction with Fred Gibson & Sons of Otley, in an effort to avoid the costly problems created, both for the knitter and the winder, when long lengths of yarn and/or cones are dispatched without being adequately lubricated. Experiments carried out with a variety of tracer materials resulted in the incorporation of a small amount of intensely fluorescent agent in the wax disc during manufacture. When placed under ultraviolet light, yarn which has been lubricated using this special wax fluoresces, whilst unlubricated yarn does not, hence, waxed and unwaxed yarn can easily be distinguished on a cone and between cones. In addition, where a portable UV inspection station is available, quality control checks can be made at each winding head and any faults corrected immediately.

The agents incorporated in the Shirley UVI Fluorescent Wax are expensive and, because of this, the UVI wax is more expensive than ordinary wax. However, it has been estimated that spoilt knitted fabric, rewinding and waxing claims etc. are costing the industry between £50,000 and £100,000 per year (1971 figures), but as the cost of waxing is so low and the penalties which have to be paid for poor waxing are so high, the extra cost is very small compared to the saving that the fluorescent wax can ensure.

Splashless Coning Oil

One of the major problems with oil lubrication has always been the amount of splashing and oil contamination which occurs during high speed winding. Benjamin R. Vickers of Leeds have developed an oil which removes this problem. Their splashless coning oil contains a tacky additive which improves cohesion between the oil and the yarn, such that splashing cannot occur even at very high winding speeds. The obvious advantages are that oil loss is reduced to a minimum, thus creating savings on lubrication and cleaning as machines and work areas remain cleaner.

3. Methods of Application

Yarn lubrication takes place during cone winding and, as previously stated, there are three basic groups or types of lubricants applied to knitting yarns; solid waxes, emulsions and coning oils. As the method of application depends primarily on the type of lubricant to be applied, individual variations between winding machines will be described under the corresponding headings.

Lubrication by Solid Wax

There are many different machines produced which lubricate yarn by means of a solid wax disc, and although the basic principles are similar, the way waxing is carried out varies according to the manufacturer.

Free Running or Gravity Waxing Unit

Probably still the most popular method of applying wax to a yarn is by means of a free running disc waxer. This consists of a waxer table with a centre peg, the whole revolving on a centre bush with point bearing. The wax ring fits over the centre peg, the centre hole, being large enough to ensure free rotation of the wax disc round the peg. In most cases, this is achieved by making the central peg slightly cone shaped. Thus, if the disc will fit over the top of the peg, it will obviously fit freely around the bottom narrower section. The yarn to be waxed is fed from the package through guides and tensioners, and is positioned so that it runs between the waxer table and the wax disc and then through guides onto the cone. Once the yarn is running, and because both the waxer table and the wax disc are free to move, both rotate at high speeds with the winding of the yarn.

An industrial example of this type of machine still in use is the Leesona M85, now designated the Leesona 360.

The main disadvantage of the free running disc waxing unit is that wax pick-up can be irregular due to the variation in yarn/wax loading with time. Usually, a wax disc of between 5/8″ and1/2″ thickness is placed on the spindle but, as the yarn is processed, this is worn away. As the thickness of the disc decreases, so also does its weight, and this leads to irregular waxing, therefore, the control of wax pick-up depends entirely on the efficiency of the operative. For example, if the wax disc is left until it has become very thin, quite large frictional variations can occur along the yarn and, as it is not common practice to load the rings, problems can arise later during knitting due to insufficient lubrication.

Probably the easiest way of counteracting this problem is by keeping two discs on each spindle, and as one runs out, placing another on the top. This method ensures that at no time during winding does the weight of wax drop below an acceptable level. Even if a new disc is not put on top until after the first ring has worn down quite considerably, sufficient wax is applied to the yarn to avoid later problems.

Loading of the disc is not common in industry because it tends to cause the yarn to be thrown out from under the wax. The explanation for this appears to be a combination of the softness of the wax into which the yarn can "bite" and its high rotational speed. The effect can be controlled by increasing yarn tension but this tends to result in a hard package which is not considered desirable.

Other disadvantages of this system of lubrication are that the wax ring tends to bounce, due to its high rotational speed and this can result in very inconsistent waxing of the yarn. Also, if fly from the yarn gets trapped between the wax disc and the peg, the wax will bind on the peg and not rotate, again resulting in inconsistent waxing. This problem may also occur if there is a build-up of fly under the wax disc on the waxer table. When this happens, the disc is lifted off the table allowing the yarn to pass underneath without coming into contact with the wax. If the wax disc stops rotating, due to the build-up of fly, the yarn starts to cut into it, which again allows wax pick-up to drop. If this continues for too long undetected, eventually the wax disc will disintegrate and the yarn will pass without being lubricated at all.

Some of the problems of the free running waxer have been overcome or reduced by fitting a mechanical escapement underneath the waxing table. This slows down the waxing table so that it no longer rotates at yarn speed and more control can be gained over the waxing process. With the wax ring and table rotating at slower speeds, the tendency to bounce is reduced and also, when there is a yarn break, less yarn is wasted. The problems encountered with this type of system however, are not insuperable and if the machines are maintained and kept clean, very efficient waxing can take place.

Power Driven Waxing Units

With the development of automatic high speed cone winders, the old method of wax application had to be adapted and developed to cope with new requirements as well as to avoid the problems that could have arisen using a free-running waxing system at increased winding speed.

Schlafhorst Autoconer

On the Schlafhorst Autoconer the waxing unit is fitted below the slub catcher mechanical clearing unit, and consists of a waxer socket, a wax roll which fits over a square drive shaft, a pusher fork and a pressure fork. The pressure fork presses the wax roll guided by the drive disc on the square drive shaft against the three supports of the waxer socket. The three supports determine the distance of the wax roll from the ceramic guides and the ceramic yarn guide ring in the middle of the waxer socket. This acts to ensure that the same arc of contact is constantly maintained between the yarn and the face of the wax roll. In this way, the application of wax is completely independent of the weight of the wax roll and thus ensures that the amount of wax applied remains constant.

The wax rolls must be smooth and rounded at one end before setting them in the machine and must be changed when they have worn down to a thickness of approximately 5mm. When replacing the wax roll, the old wax is removed from the shaft and a new roll put on, rounded end first. Then the carrier disc, which is first removed from the old wax, is pushed into the square back of the new roll so that the carrier pins are completely embedded. The penetration of the pins is usually about 5mm which explains why the old wax must be removed when it has worn down to this thickness. If the wax is not changed at this point, the yarn can catch in the carrier pins and break.

Schweiter CA11

The Schweiter CA 11 automatic cone winder can also be supplied with a waxing attachment on request. The wax roll is held in position on the drive shaft by means of a metal plate behind which is a spring. At the other end, the wax roll presses against an adjustable counter-pressure plate, the yarn being drawn between this and the wax roll in the straight line of the yarn path. Constant pressure and wax/yarn contact is maintained by the spring positioned behind the plate. Therefore, as the wax wears away the effect is counterbalanced, so that regular and even waxing of the yarn is ensured.

Gilbos Conematic M3

The Gilbos Conematic waxing device differs slightly from the Schlafhorst and the Schweiter automatic models in so much as the wax roll is positioned in front of the yarn instead of at the side, the yarn passing behind the disc and held in position by the guides. The disc is, however, mounted on a square shaft and each head is driven individually by an independent motor.

Leesona Uniconer

On the Leesona Uniconer, the waxing assembly differs only slightly from the arrangement on the Leesona 360. On this machine, the waxer table is held static and the wax disc is rotated in the same direction as the yarn at a standardised speed. The r.p.m. of the wax has been calculated to give optimum waxing under normal conditions, therefore, if a higher percentage uptake of wax is required, this can only be achieved by using a softer wax disc, i.e., one with a lower melting point.

Savio RSA

The wax disc on the Savio RSA automatic winder is mounted on the side of the yarn although, as in previous cases, it does not deflect the yarn from its straight path. The yarn passes between the wax and an adjustable pressure plate so that a different wax application can be arranged by changing the pressure of the plate. This is achieved by adjusting the dials on a centralised control panel to change the pressure from the pneumatic feed.

The above describe the most common arrangements for waxing yarn on free running and automatic winding machines. Other manufacturers may vary slightly, but basically, the principles and objectives are the same, i.e. to lubricate the yarn as uniformly and regularly as possible, without unduly hindering the path of the yarn from the supply to the cone. Although constant application of the wax is more closely and accurately controlled on the automatic cone winders, similar problems, due to fly and wax deposits can be encountered as mentioned for the free running waxer unit. However, if the machinery is correctly cleaned and maintained, there is no reason why yarns cannot be successfully lubricated on any of the machines described.

Although, under normal conditions, waxing takes place immediately before collection onto the cone, in some circumstances it becomes necessary to give the yarn a pre-waxing treatment to aid the traverse of the yarn through the machine. In these cases, the wax is applied immediately the yarn is pulled from the spindle. As the yarn is drawn from the spindle it balloons out and, therefore, to apply wax at this stage two wax discs are placed at either side of the balloon. Then, as the yarn forms the balloon, it just catches the surface of the wax and in this way, enough wax is applied to avoid processing problems and aid the yarn through the winding process. It must be emphasised however, that this is not a common method of applying wax and it is only done when the yarn, usually worsted or acrylic, is particularly difficult to process.

Lubrication by Emulsions

Although, in the majority, staple yarns are lubricated by solid waxing devices, it is not practical to lubricate continuous filament yarns in this way. The main reason for this is that continuous filament yarns cut into the wax disc very quickly causing rapid disintegration of the wax solid and, therefore, inconsistent and inefficient lubrication. On the whole, continuous filament yarns are lubricated by the application of oil during winding, but both continuous filament and staple yarns can also be adequately processed by applying a wax emulsion.

Roller and Trough Application

The most popular method for applying wax emulsion and oil lubricants to a yarn is by the roller and trough technique. The basic principle is that a roller is partially immersed in a trough containing emulsion. The level of the lubricant is controlled from a supply at one end of the machine and both the supply and the trough are maintained at a constant temperature to ensure constant viscosity of the wax. The roller is rotated in the trough and in doing so, picks up a film of lubricant on its surface. The yarn is then guided over the roller at an angle of wrap of about 5°, through tensioners and guides and, therefore, picks up some of the emulsion. Pick up levels are adjusted according to the requirements by changing relative speeds of the roller and the yarn and the angle at which the yarn passes over the roller.

The main disadvantage with emulsion lubrication - and this also applies to oil lubrication - is the fouling of the winding machine, floor and atmosphere, due to the spraying of the lubricant as the yarn runs over the roller. In addition, when processing staple yarns, yarns of different colours cannot be processed through the same trough, owing to the risk of contamination by fibres being transferred in the emulsion. On some yarns, particularly the hydrophobic synthetic yarns, the inevitable rise in moisture content may be undesirable; with hydrophilic yarns, problems can result from differential drying of the packages prior to knitting.

On the other hand, the advantage of this method of waxing is that it is easier to see when the yarn is not being lubricated properly; for example, if the yarn is not picking up emulsion due to an incorrect setting of the yarn path over the roller, or if the roller is not picking up emulsion from the trough because the level has fallen or the surface of the roller is dirty. However, the main problem of splashing makes this method of application less popular for staple yarn lubrication than that of the solid wax disc.

Lubrication by Coning Oils

As previously stated, it is impractical commercially to lubricate continuous filament yarns with a solid wax disc, and it is also uncommon to find wax emulsions used for this purpose. The majority of continuous filament winders use a coning oil to give lubrication to the yarns, and the machines are equipped for this purpose. The most usual method of application is by the roller and trough technique, previously described, although individual manufacturers have adapted this method to suit their own particular machines and requirements.

Schweiter Precision Cone Winder PC 20

This machine, specially designed for the precision winding of pineapples up to 11 lb (5 Kg), is equipped with individual roller and trough lubrication units at each winding head. Each trough has an individual feed pipe to maintain a constant level of lubricant, and the troughs are situated on the machine just before the collection of the yarns onto the packages.

Schweiter KE Series

On the precision coners of the KE series each winding head has an individual roller but the trough is common to all and runs the width of the machine. The level of lubricant in the trough is maintained from a feed at one end of the machine and the amount applied adjusted by stepless regulation of the oiling device drive. However, to overcome the problem of splashing and oil loss on these machines, Schweiter have developed an easily fitted attachment. This consists of a transparent oil spray shield in the form of a double chamber which catches the oil sprayed and leads it back into the oil trough. To be used in conjunction with the oil shield, Schweiter have also developed a fluted roller which they claim allows the oil application rate to be raised by about 6% without increasing yarn speed. The action of the roller, which is axially fluted is to 'ladle' the oil into the yarn and this is why it is possible, in conjunction with the oil shield, to increase application while cutting oil loss and contamination due to splashing.

Schärer Precision Cone Winder

The oiling device on the Schärer Cone Winder also consists of individual rollers revolving in a common trough, running the length of the machine, which is maintained at a constant level by an oil feed at the end. However, on this model, the amount of oil being applied by the roller to the yarn is kept constant automatically by an 'oil compensating device'. As the take-off speed increases, the pre-tension device is gradually pushed sideways so that the yarn path is deflected slightly and the yarn passes over the roller obliquely. The increased contact time is calculated to compensate for the increased yarn speed thus avoiding problems due to under-lubrication when the yarn is being wound at a higher speed. There are 24 options available for regulating the speed of the oil roller and when oiling is not required the roller can be moved sideways out of the way of the yarn path.

Wicking

Although the roller and trough technique is the most popular method for applying liquid lubricants, there is also another method available. This method, known as wicking, consists of passing the yarn through a slit in a hard felt wick, the other end of which is immersed to a certain level in the lubricant. The principle behind this method, is that the felt absorbs the lubricant and when the yarn is passed through the slit, the felt deposits the lubricant onto the yarn.

Pick up is adjusted by increasing or decreasing the thickness of the wick thereby modifying the length of time of the yarn/wick contact. Although this method can be used successfully, the main problem in practice is that the yarn tends to cut into the felt, necessitating very hard wicks to be used.

A modification of this technique interposes a roller between the wick and the yarn. The wick absorbs the lubricant and deposits it onto the roller which in turn deposits it onto the yarn as the yarn passes over the roller. This avoids the problem of cutting of the felt by the yarn, but unfortunately it is very difficult to maintain sufficient pick up of the lubricant by the yarn for adequate lubrication.

Dipping

The final method of applying a lubricant takes place after winding and can be used for any type of yarn. In this case, the nose of the cone is dipped into the lubricant up to about 1", the theory being that the yarn will act as a wick and draw up the lubricant. In most cases, however, because pick-up cannot be accurately controlled, this method is generally discounted. There are, however, firms in operation who lubricate the yarn before knitting by this method, and achieve acceptable results.

NB: Open-end Yarns

Open-end yarns can be lubricated in the same way as any other staple yarn. However, some of the latest open-end spinning machines now have integral lubrication devices built in so that the yarn receives a degree of lubrication immediately after spinning.

4 Criteria for Obtaining Optimum Lubrication

The main reason a yarn is lubricated and, therefore, the main function of a lubricant is to reduce the coefficient of friction of the yarn to its lowest possible level. To evaluate various types of lubricants, their performance under different conditions, and the optimum conditions for lubrication necessary to obtain minimum friction, the Hosiery and Allied Trades Research Association, (HATRA) carried out a series of research projects on different types of yarns. The experimental results and conclusions they reached are published in the HATRA research reports 22-24, extracts of which are given below.

NB: The conclusions and recommendations are based almost exclusively on the lubricating effect of the particular lubricants and methods used.

Staple Yarns

Worsted

Quantity, quality, and consistency are the chief requirements for optimum lubrication.

Quantity

1. A certain minimum quantity of lubricant is required for lubrication and beyond a certain optimum level, friction is likely to rise (*Figs 2 & 3*).
2. Optimum quantities conveniently cover a range of approximately 0.5 µg/cm to 3 µg/cm for constant friction commercial hosiery yarns (*Fig 2*).
3. These levels can be obtained by free-running or powered disc waxers and, if both are properly used, there is no significant difference in results. The former applies optimum levels at wax loadings of 10-20 g. This provides a convenient assessment and quality control parameter. Loadings for the latter vary with type (*Figs 2 & 4*).
4. The distribution of wax on the yarn at the waxer is not important so long as quantity is maintained, since redistribution takes place at the running surface (*Fig 5*).

Quality

1. Paraffin waxes have been found to give the best results, though some other lubricants can match these (*Figs 6 & 7*).

Consistency

1. Consistency within yarns and between yarns is important in order to maintain quality, dimensions and yield properties (*Figs 8 & 9*).
2. Short term variation of lubricant pick-up is insignificant provided total quantities are maintained.
3. Long term variations of pick-up - greater than 5-10 yards - are undesirable.
4. Re-winding can occasionally improve consistency (*Fig 10*).

Other Considerations

1. It was found that optimum friction levels obtained at wax loadings between 10 and 20 g were successively lower as the melting point of the wax increased (*Fig 6*). Also that the rate friction increases after 20 g varies with the melting point of the wax, i.e. the higher the melting point, the slower the increase in friction levels as wax loading increases.

2. The effect of dyeing on friction levels was found to be controllable and all variations discovered (after processing) on the unlubricated yarn levelled out when lubricated using solid wax discs at a loading of 10 g and over.
3. The effect of winding speed, temperature at winding, the relative humidity and yarn regain at winding were found not to be significant within commercial limits.

Cotton

Quantity and quality of the lubricant and consistency of application are the three criteria that determine optimum lubrication of cotton yarns.

Quantity

1. A certain minimum quantity of lubricant is required for optimum lubrication and beyond a certain level of wax pick-up, friction is likely to rise (*Fig 11*).
2. The wax pick-up can be maintained between these levels using the free-running disc waxer by maintaining the wax/yarn loading between 10-20 g (*Fig 11*). This may be conveniently achieved by placing two wax discs on the waxer and a further disc on the top when the lower disc wears away.

Quality

1. Paraffin waxes have been found to give adequate lubrication for cotton yarns.
2. The melting point of the paraffin wax affects the minimum friction obtainable. Waxes melting in the region of 140 °F give the lowest friction. The wax melting in the 140-145 °F range maintain the minimum friction over the widest range of wax disc loadings (*Figs 12 & 13*).
3. Silicone additives improved the lubricating properties of paraffin wax at impractically high wax loading only: in the recommended range of loading plain paraffin wax gave superior results (*Figs 14 & 15*).

Consistency

1. Consistency of friction between and within yarns is important to maintain fabric quality, dimensions and yield (*Fig. 16*).
2. Consistent friction can be obtained by attention to wax loading levels and while the amount of wax picked up may vary (*Fig. 17*), the effect on the friction is minimal (*Figs 11 & 12*).

Other Considerations

1. Yarn condition has an effect on yarn friction which should be taken into account in storing waxed or unwaxed cotton yarns (*Table 3*).
2. Yarn scouring and dyeing can increase yarn friction, but waxing, according to the above recommendations can reduce the friction to an acceptable level (*Fig. 18*).
3. Softening agents applied in the dyebath do not necessarily have a lubricating effect in knitting (*Fig. 18*).

Acrylic

It has been reported that certain firms prefer to knit unlubricated acrylic yarns because they are unable to obtain consistently lubricated ones. Since consistency of lubrication is important, this approach is not without some merit, but it is clear from the work reported that both consistency and optimum lubrication can be achieved by fairly simple control of yarn waxing.

Quantity, quality and consistency are again the chief requirements for optimum lubrication and, given these three, most staple acrylic yarn can be adequately lubricated for knitting.

Quantity

1. A certain minimum quantity of lubricant is required for optimum lubrication, and beyond a certain level, friction is likely to rise (*Figs 19, 20 & 21*).
2. Optimum levels can be obtained by free-running or powered disc waxers and, if both are properly used, there is no significant difference in the results. The former applies optimum levels of wax at loadings of 10-20 g (*Fig 19*). This provides a convenient assessment and quality control parameter. Optimum loadings for powered waxers vary with type.
3. The distribution of wax on the yarn at the waxer is not important so long as the quantity is maintained, since re-distribution takes place at the running surfaces.

Quality

1. Paraffin waxes have been found, consistently, to give the best results though some other lubricants can approach these (*Figs 22, 23 & 24*).
2. The presence of low molecular weight compounds in the wax can result in swelling of acrylic fibre and an increase in yarn/metal friction (*Figs 25 & 26*). Fully refined paraffin waxes avoid this problem.
3. High melting point paraffin waxes have been found to be significantly preferable for lubrication.
4. Softeners may have the effect of increasing the yarn/metal friction of acrylic yarns (*Figs 22 & 24*).

Consistency

1. Consistency within yarns and between yarns is important in order to maintain quality, dimensions and yield properties (*Table 6*).
2. Short term variation of lubricant pick-up is insignificant, provided total quantities are maintained.
3. Long term variation of pick-up, greater than 5-10 yards, is undesirable.

Other Considerations

1. The production of fly which presents problems with acrylic yarns is reduced by adequate lubrication (*Fig. 1*).

Continuous Filament yarns

Whilst the choice of lubricant for continuous filament yarns is related to such factors as cost, scourability, colour and oxidation resistance, the primary requirement is that of producing adequate and consistent reduction of frictional forces in knitting.

Quantity

1. A certain minimum quantity of lubricant, about 1½%, is required for optimum lubrication and, although levels appreciably above this do not affect the frictional characteristics, they are commercially undesirable (*Fig 27*).
2. Optimum levels can he obtained by using a roller and trough or a wick, though both of these methods require the acceptance of a tolerance in commercial application (*Fig 28*).
3. The distribution of the lubricant on the yarn is not important, so long as quantity is maintained, since re-distribution takes place under the action of capillary forces and at running surfaces (*Fig 29*).

Quality

1. The levels at which friction is optimum depends on the lubricant used. Although these levels vary, lubricant choice may require other factors to be considered (*Fig 30*).
2. The presence of "swelling agents" in the lubricant not only affects the frictional level, but can cause surface damage to the fibre (*Tables 7, 8, and 9*).
3. Lubricants having an equivalent effect on polyester and polyamide yarns are commercially desirable.

Consistency

1. Consistency within yarns and between yarns is important in order to maintain quality, dimension and yield properties.
2. Short term variation of lubricant pick-up is insignificant, provided that the total quantities are maintained (*Fig 28*).
3. Long term variation of pick-up, greater than 2 metres, is undesirable (*Fig 28*).

Other Considerations

1. The side effects of the lubricant on the yarns and surfaces with which it comes into contact are important. Such factors as swelling (*Tables 7, 8 and 9*), filament damage, rubber degradation (*Table 10*) and needle corrosion (*Fig 31*) require consideration.
2. Quality control when lubricating continuous filament yarns is as much a function of the lubricant viscosity as of the method of application. The concept of yarn dwell time for a roller and trough applicator is of value when attempting optimum lubrication. The temperature at which the lubricant is applied affects, by the change in viscosity, the pick-up levels obtained (*Figs 32, 33 and 34*).

5. Quality Control of Lubricants

Stringent quality control in the manufacture of yarn lubricants is essential as any impurity or untested ingredient in the lubricant can lead to problems in winding, knitting and finishing. New ingredients must be thoroughly tested to ensure that they do not affect either the yarn or textile machinery with which they might come into contact. This is probably of greater importance in the manufacture of coning oils where, in general, more additives are included in the final product than normally found in solid waxes.

The requirements for a good coning oil are given below and, although they relate specifically to coning oils, these requirements can be used as basic criteria for all yarn lubricants.

- Optimum frictional properties.
- Good cohesive properties.
- Good anti-static protection.
- Good scourability.
- Good rubfastness properties.
- Non-oxidising.
- Non-volatile.
- Non-dermatitic.
- Non-corrosive to metals commonly encountered in textile machinery.
- Non-reactive to yarns.
- Good product stability.

6. Removal During Finishing

It is essential that all yarn lubricants should be easily removable during finishing, as their continued presence can seriously affect certain finishing procedures. According to the producers, removal should not be a problem as this is tested as part of their quality control procedures. Some solid waxes and the majority of oils contain emulsifiers as a basic ingredient especially to aid removal, but even lubricants which do not contain emulsifiers should come out of the fabric without problems during finishing because of the presence of emulsifiers or surface active agents in the finishing liquors.

To make doubly sure that complete removal is achieved, some producers recommend scouring recipes, especially if a particular lubricant could prove difficult to remove e.g. Benjamin R. Vickers include a recommended scour for some of their coning oils on the specification and performance data sheet.

7. The Cost of Lubrication

The cost of obtaining optimum yarn lubrication is relatively very small, as it is an auxiliary to winding and does not require a separate process. The charge to the winder for solid wax discs varies according to quality and specifications, but is usually in the range of £0.15 - 0.20 per kilo. Obviously, the number of wax rings per kilo, and therefore the number of winding heads supplied, will vary according to the weight and size of the individual disc but, with optimum pick-up of between 0.1 and 0.25% of wax per weight of yarn it is apparent that many pounds of yarn can be lubricated from 1 kilo of wax discs.

The cost of oil lubrication is in a similar range. Benjamin R. Vickers quote their oil prices as varying between £210 - 230 per metric tonne. With optimum application levels of between 2% and 4% per weight of yarn, the cost of lubricating a kilo of yarn works out at under half a penny.

6. CONCLUSIONS

Yarn lubrication is a large and specialised subject which makes it difficult to cover every aspect in detail. This study report deals almost exclusively with the lubrication of yarns for weft knitting, as it is in this area that excessive tensions caused by high frictional coefficients on the yarn can cause the most problems. Lubrication takes place during winding and if the correct lubricant is applied for the type of yarn being processed and the conditions in the mill, and the machinery is adequately maintained, the problems of badly lubricated yarn should be avoided.

NB: The lubrication of warp knitting yarns has not been included because the majority of warp knitting yarns are continuous filament and receive a spin (or producer) finish after spinning. The lubricant is applied just after fibre extrusion and prior to drawing in the form of an emulsion so as to obtain a uniform application of finish of the order 0.5 - 1.0% at a precise moisture level. Additional lubrication after this does not normally take place because handling of the yarn must be kept to an absolute minimum if knitting problems are to be avoided. Where staple yarns are used however, they can be lubricated by any of the methods previously described during a winding process, or by roller and trough during warping.

Table 1

Theoretical Variation of Output Tension (To) with Angle of Wrap
for an Input Tension (Ti) of 2 grams.

Coefficient of Friction $\mu = 0.167$

Angle of wrap, deg	15	30	45	60	90	120	150	180
Output tension, g	2.09	2.18	2.28	2.38	2.53	2.84	3.10	3.38

Table I shows the effect of changing the angle of wrap of the yarn about the contact surface.

Table 2

Theoretical Variation of Output Tension (To) with Number of 90° Contacts
for an Input Tension (Ti) of 2 grams.

	Output tension for the given Number of 90° contacts						
Number of contacts	1	2	3	4	5	10	20
$\mu = 0.142$	2.50	3.13	3.9	4.88	6.10	18.6	173.4
$\mu = 0.258$	3.00	4.50	6.75	10.1	15.2	115.2	6640

Table 2 shows the effect of the number of 90° contacts on the yarn tension, supposing different frictional properties to be relevant.

Although these tables do not necessarily represent machine conditions, the calculations relate the effect of friction and the order of tensions involved and give some indication of the potential value of lubrication in lowering yarn tension by reducing frictional coefficients.

Table 3

The effect of Yarn Condition on Friction

Yarn Condition	To / Ti
Wet out and hydroextracted	2.00
Standard condition (65% RH)	1.55
Oven dried	1.46

Due to variable conditions of storage and use, cotton yarns will vary in the amount of absorbed water they contain. To determine whether or not this had any effect on yarn friction, a cone of waxed cotton yarn was taken and divided into three parts. One part was oven dried, another conditioned in a standard atmosphere, and the remaining one thoroughly wetted and the excess water hydroextracted. The friction of the treated yarns was measured.

From the table, it can be seen that friction decreases as moisture content decreases. Experience shows, however, that some moisture is required in cotton yarn and it is not desirable to attempt to dry the yarn completely to obtain a low friction. Instead, by careful attention to conditions of storage and use, a constant moisture level should be maintained.

Table 4

Swelling of Courtelle Fibres*

Treatment	Fibre Diameter	Swelling %
Untreated	0.0595	~
Slack Wax	0.0653	17
DEV 169	0.0684	22

* *Editor's note December 2008*

It is not clear how the swelling figures given in column 3 of this table have been calculated. Based on the given diameters, the percentage changes in cross-sectional area were 20.5 and 32.2.

Table 5

Properties of n-alkanes

Alkane	Molecular Weight	Melting Point °C
n-decane	142.2	-29.7
n-dodecane	170.2	-9.6
n-tetradecane	198.2	6.0
n-hexadecane	226.3	18.0
n-octadecane	254.3	28.0
n-eicosane	282.3	36.8
n-docosane	310.4	44.1
n-tetracosane	338.4	51.0
n-hexacosane	366.4	56.0
n-octacosane	394.5	64.5

Table 6

Lubrication of Acrylic Jacquard Fabric

Property	Fabric 1 Under-lubricated	Fabric 2 Adequate lubrication
Average course length per six pattern repeats, in	14.7	15.4
Weight per running yard, g	421.0	371.0
Area weight, g/sq yd	483.0	426.0
Pattern repeats per running yard	22.0	20.25
Patterns per square yard	429.0	379.0
Faults in the ratio	3.0	1.0
To / Ti	1.49	1.375

Acrylic Jacquard Fabrics 1 & 2

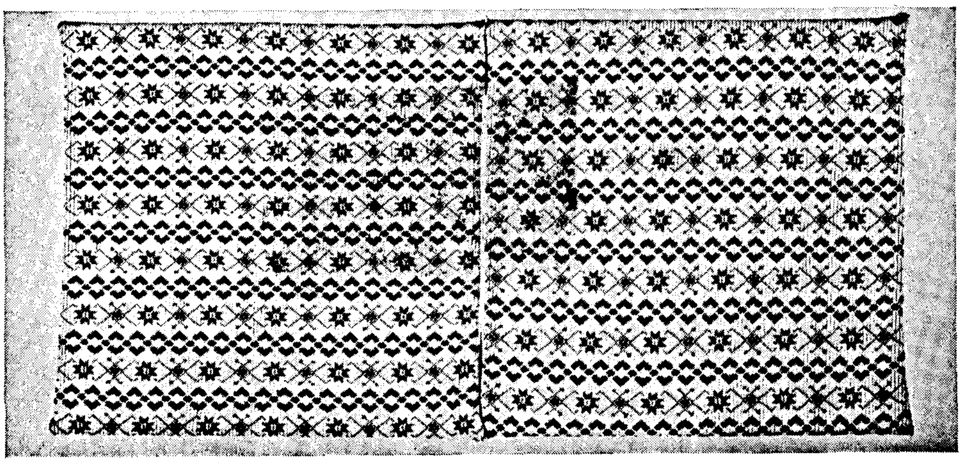


Table 7

Swelling of Nylon and Polyester Fibres in Oil*

Yarn	Lubricant	Diameter before	Diameter after	Swelling %
Nylon 66	oil 1	0.0574	0.0599	11¼
	oil 2	0.0574	0.0598	10½
Polyester	oil1	0.0575	0.0596	9½
	oil2	0.0575	0.0727	67

* *Editor's note December 2000*

> *It is not clear how the swelling figures given in column 5 of this table have been calculated. Based on the given diameters, the percentage changes in cross-sectional area were 8.9, 8.5, 7.4, and 59.9.*

Since certain oils have been shown to increase rather than reduce the friction of a number of the continuous filament yarns, particularly polyester, some experiments were carried out in order to investigate this phenomenon. Table 7 shows the results of tests carried out with nylon and polyester fibres. Swelling of both nylon and polyester takes place; with oil 2 on polyester fibre, swelling is substantial and is presumably associated with some modification of the fibre surface. This was confirmed when the yarn was photographed in a scanning electron microscope; surface damage was easily detected. It can also be shown that certain types of dirt can be carried onto the damaged surface by a contaminated 'swelling oil' and cause semi-permanent soiling. This fact is of significance in relation to machine oils as well as lubricants.

In tests carried out using n-alkanes, swelling of about 10% occurred in nylon and polyester. However, as the degree of swelling did not approach the degree found in some previous measurements, it was considered unlikely that any n-alkane content was responsible.

Table 8

Swelling of Polyester Fibre in Various Chemicals After 4 Hours

Chemical	Swelling %	Comment
benzene	12½	
toluene	14	
xylene	1	
phenol	15½	0.5% in liquid paraffin
orthocresol	13	0.5% in liquid paraffin
metacresol	13	0.5% in liquid paraffin
paracresol	17½	0.5% in liquid paraffin
nitrobenzene	7	
aniline	15½	
α naphthol	16	10% in alcohol
β naphthol	16	10% in alcohol
diphenyl	23	5% in 0.1N Sodium Hydroxide
orthophenylphenol	14	5% in 0.1N Sodium Hydroxide

The extreme case of fibre swelling followed by total decomposition is that obtained with recognised solvents for the various fibres, for example phenol and cresols. The swelling property, in dilute solutions of various chemicals, is a major requirement for efficient carrier dyeing of polyesters and, clearly, these compounds are to be avoided as impurities in lubricants.

Some chemicals having molecular configuration similar to these of carriers were tested. The results are shown in *Table 8*. It is possible for some of these compounds to appear as impurities or decomposition products in emulsifiers, antioxidants and anti-static agents, and thence to find their way into lubricants.

Table 9

Swelling of Polyester Fibre in various Chemicals After 4 Hours

Chemical	Swelling %
cyclopentane	13
cyclohexane	12
cyclohexanol	17
cyclohexanone	15
tetrahydronaphthalene	12
decahydronaphthalene	14
pyridine	11
quinoline	11
n-decane	11
n-dodecane	11
n-tetradecane	9
n-hexadecane	8
n-octadecane	2
n-eicosane	4
n-docosane	2

Heterocyclic compounds, which are most likely to occur in the base oil, can also cause swelling. Some were tested and the results are shown in *Table 9.* Similarly, some of these could occur in emulsifiers or anti-static agents.

Table 10

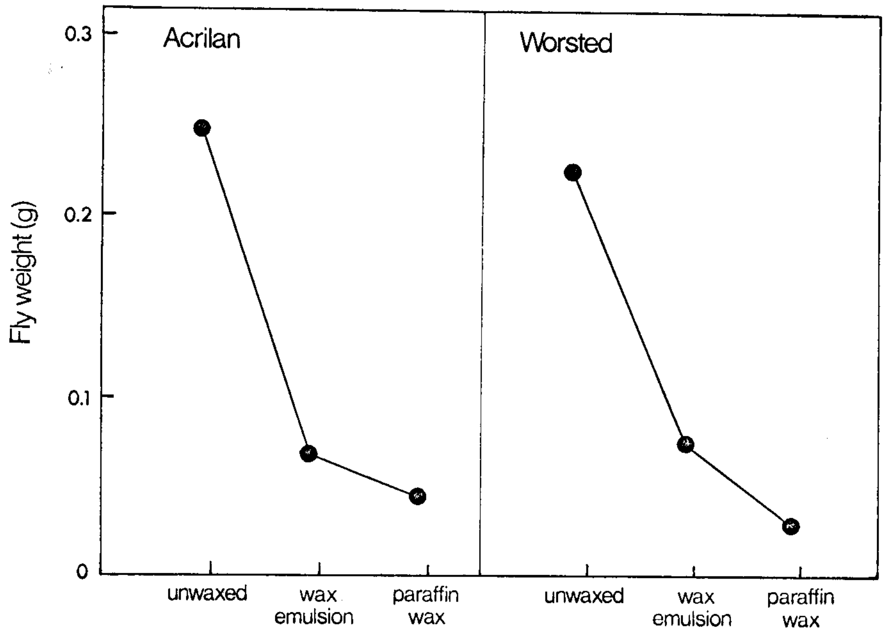
The Effect of Various Lubricants on Elastomeric yarns

Lubricant Type	Lubricant	*To / Ti* of lubricated yarn			
		Rubber	Lycra	Spanzelle	Glospan
~	none	2.40	2.34	2.20	2.50
Solid	paraffin wax	1.79	1.54	2.10	1.62
	commercial dry powder	1.36	1.65	1.86	1.35
	French chalk	1.29	1.46	1.42	1.38
Liquid	PEG 200	1.28	1.41	1.45	1.25
	commercial polyethylene type	1.24	1.41	1.49	1.38
Mineral oil	commercial lubricant	1.91*	1.25*	1.71*	1.33*
Synthetic oil	commercial synthetic lubricants	1.23*	1.35*	1.45*	1.38*
		1.23*	1.21*	1.36*	1.31*

* *The appearance and tackiness of the thread indicated that it was physically damaged by the lubricant.*

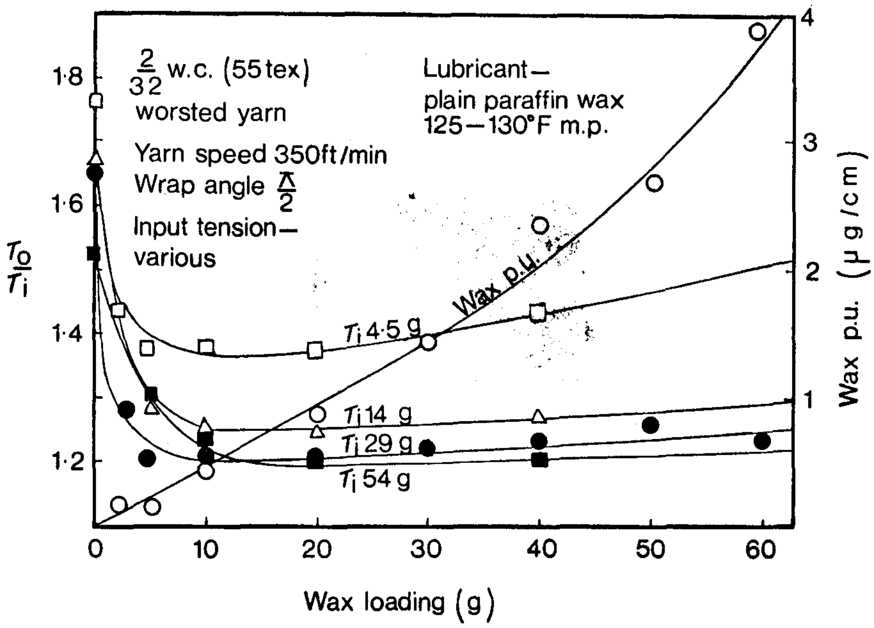
These results indicate the wide range of effects that lubricants have on elastomeric yarns both with regard to lubrication and to the damage they can cause. For example, the mineral and synthetic oils in the last three rows all affect the visible surface of the elastomer and, in the case of rubber particularly, produce high frictional effects. The damage caused to rubber by some oils has been discussed previously in HATRA Note 9, and is also of significance in relation to rubber-covered equipment, such as positive feed devices. The polyethylene type lubricants, however, produce low friction and appear to be satisfactory in other respects. There is a case for using these on any yarn which is likely to come into contact with rubber.

FIGURE 1



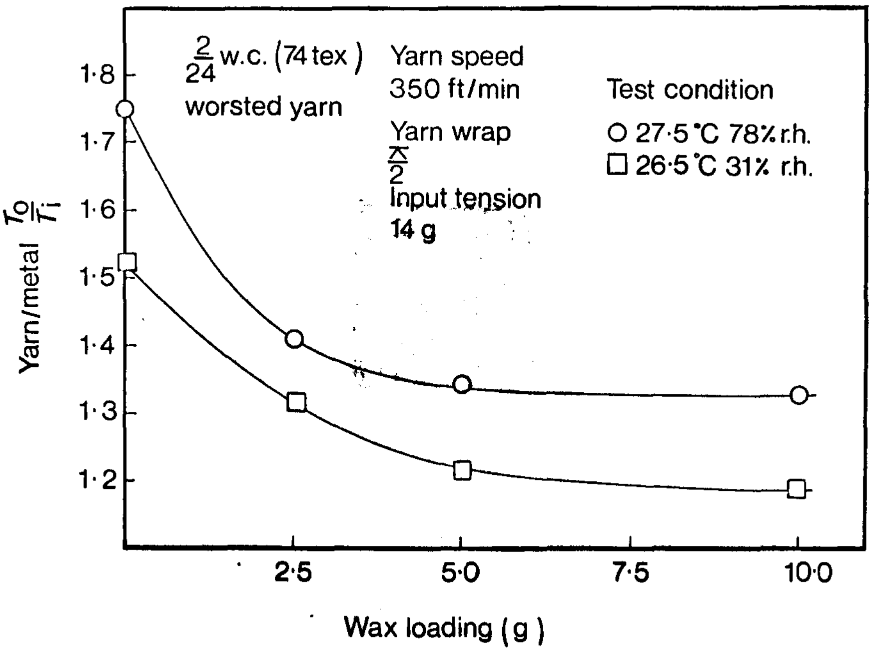
FLY REDUCTION BY LUBRICATION (3000 YARDS OF YARN KNITTED)

FIGURE 2



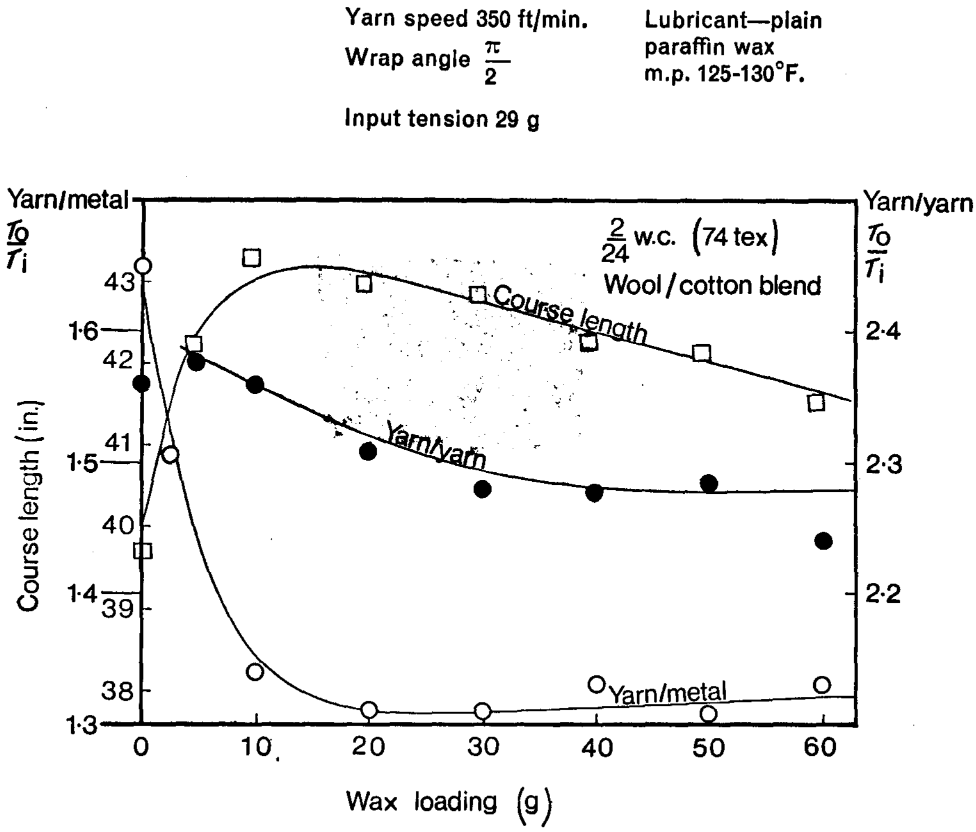
YARN-METAL FRICTION (T_o/T_i) AT VARIOUS TENSIONS AND WAX PICK-UP AGAINST WAX LOADING

FIGURE 3



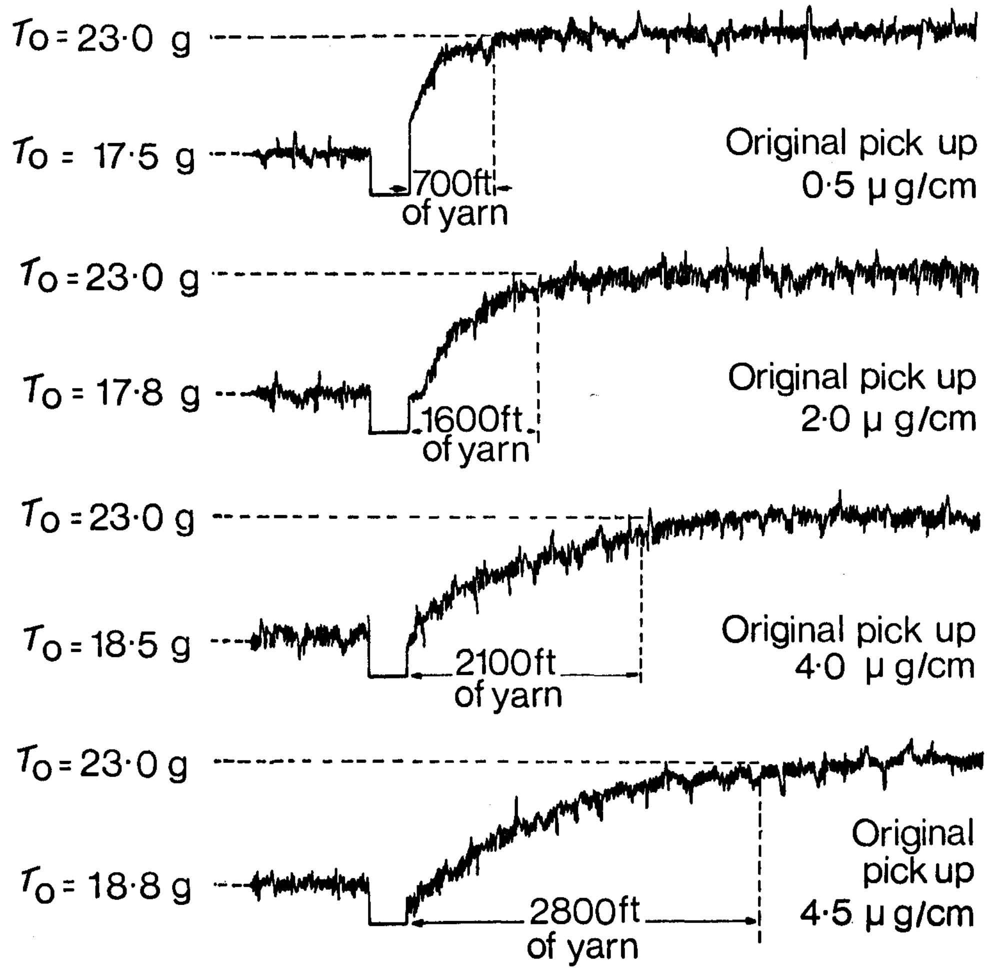
EFFECT OF TESTING CONDITIONS ON RELATION BETWEEN FRICTION (T_o/T_1) AND WAX LOADING

FIGURE 4



YARN/METAL, YARN/YARN FRICTION (T_o/T_1) AND KNITTED COURSE LENGTH AGAINST WAX LOADING.

FIGURE 5

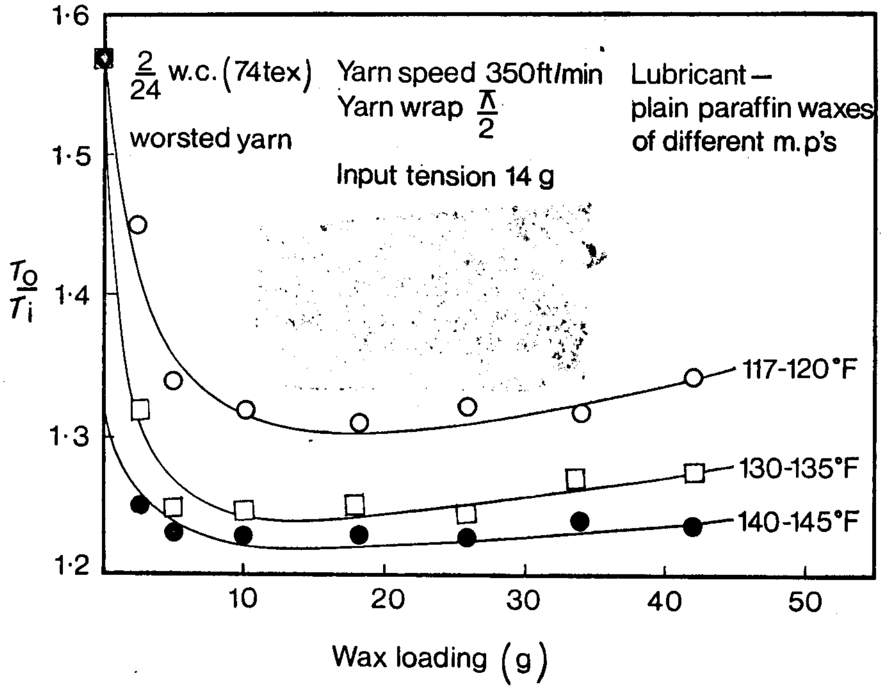


EFFECT OF CHANGES IN WAX CONTENT ON YARN/METAL FRICTION

Wax was applied at different levels to sample lengths of scoured worsted yarns. Each of these samples was followed by a length of unlubricated scoured yarn and, in this sequence, they were run through the friction tester.

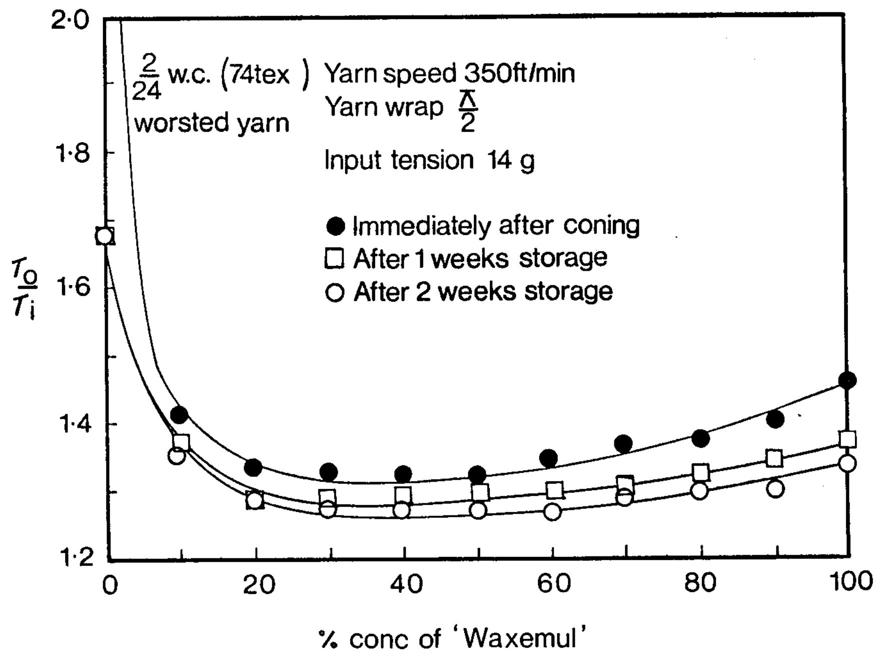
Figure 5 shows the traces obtained from the friction tester and from these it can be clearly seen that there is a length of yarn immediately following the lubricated sample which does not register the high friction levels of totally unlubricated yarn. As the amount of wax put onto the yarn, i.e. the pick-up is increased, the length of yarn immediately following the lubricated sample increases. This is explained by the theory that wax is deposited on the contact surfaces and is only gradually worn away by the unlubricated yarn passing through.

FIGURE 6



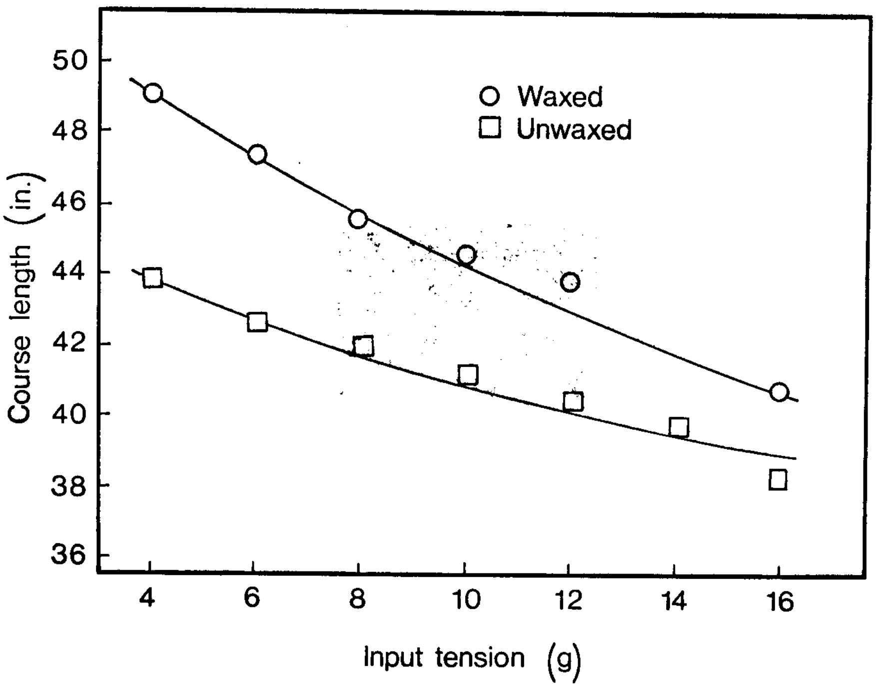
EFFECT OF DIFFERENT PARAFFIN WAXES ON RELATION BETWEEN FRICTION (T_o/T_1) AND WAX LOADING.

FIGURE 7



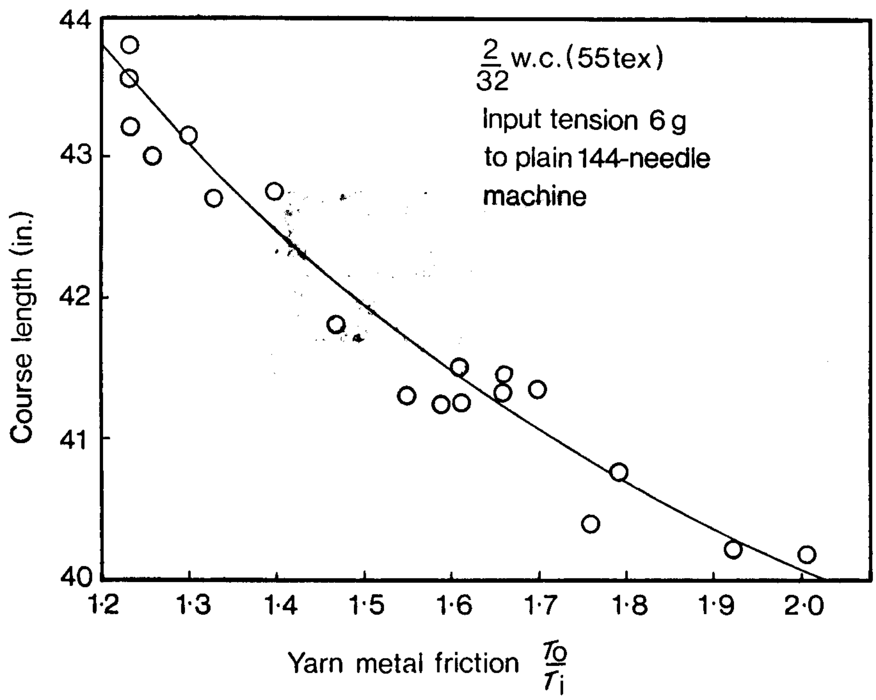
EFFECT OF WAXEMUL (WAX EMULSION) CONCENTRATION (APPLIED AT 800ft/min) AND STORAGE ON YARN/METAL FRICTION (T_o/T_1).

FIGURE 8



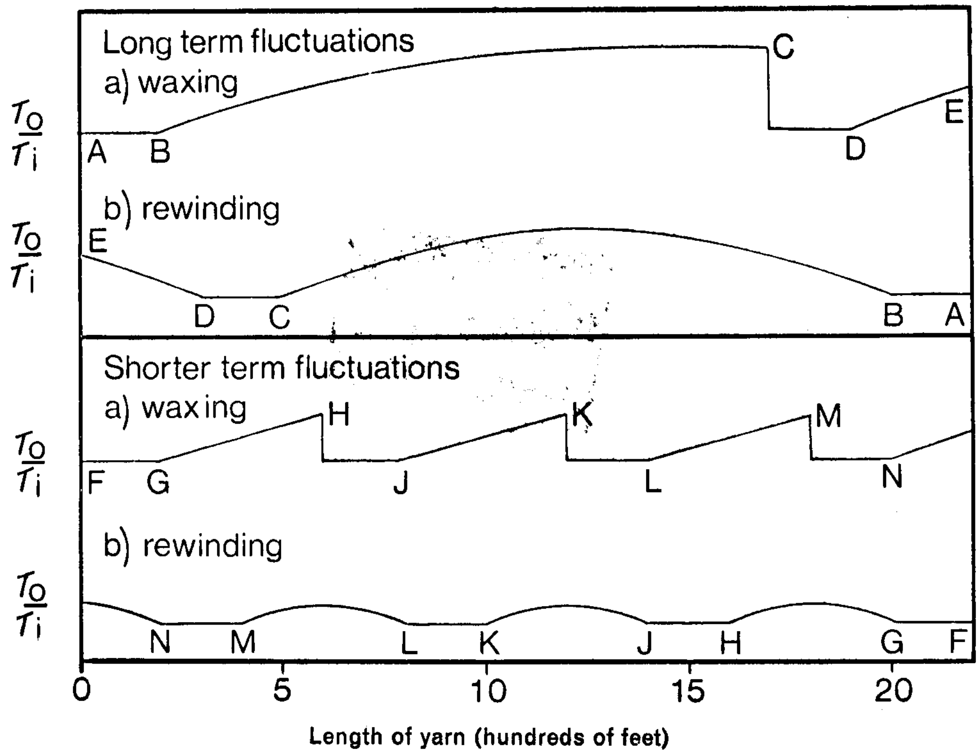
COURSE LENGTH AND INPUT TENSION.

FIGURE 9



EFFECT OF YARN/METAL FRICTION ON COURSE LENGTH.

FIGURE 10

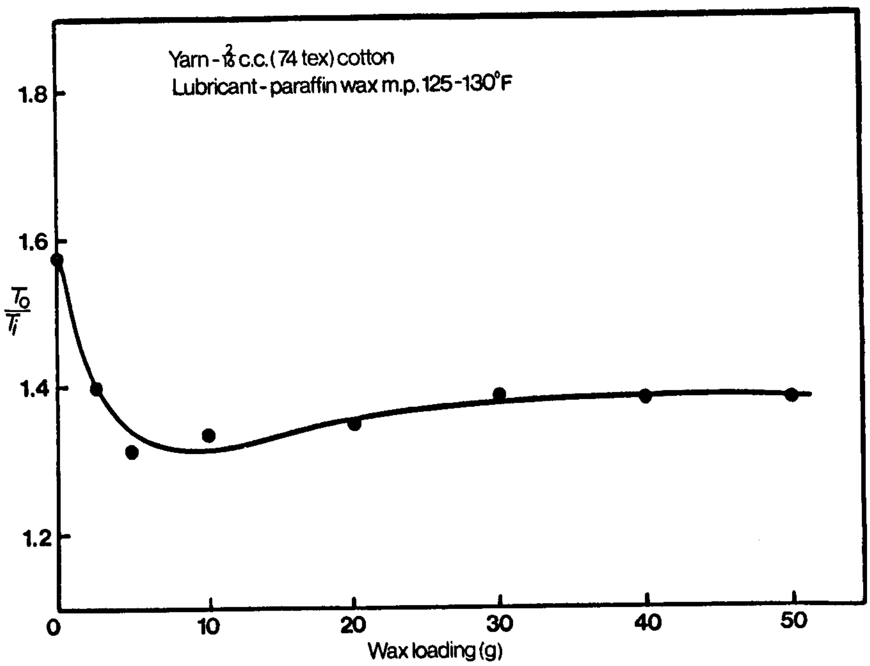


EFFECT OF REDISTRIBUTION OF WAX IN REWINDING AND KNITTING

The redistribution of wax demonstrated in *Figure 5* can have some significance in certain circumstances in the context of rewinding.

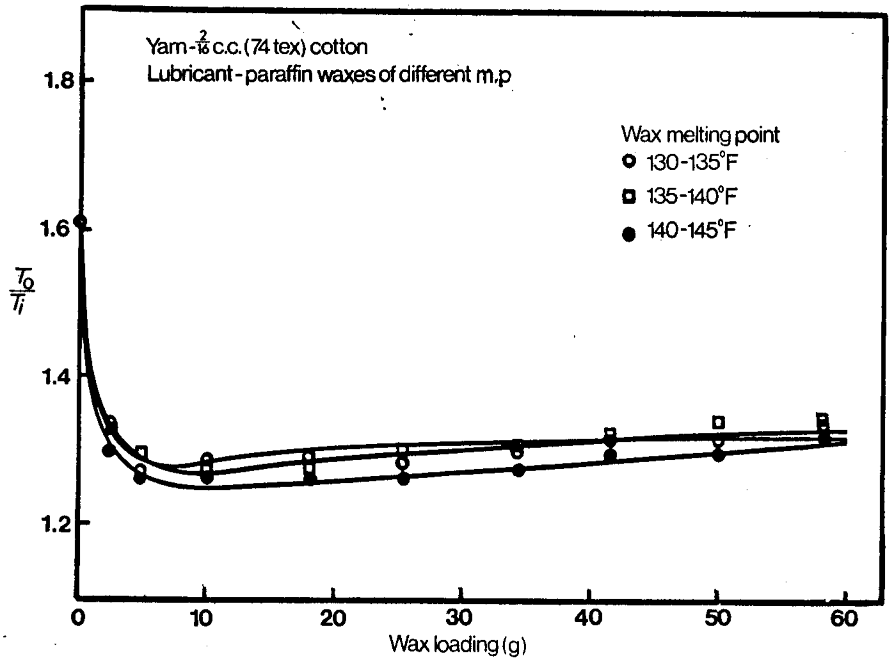
If circumstances exampled in *Figure 10* apply, it is possible to rewind yarn to advantage. At point A, lack of supervision causes a long-term break, BC, in waxing of the order of 1500 feet. This will cause high output tension at C, where the discontinuity is rectified. This yarn might be unsatisfactory on the knitting machine whereas rewinding (b) taking account of the redistribution of wax in this operation, will substantially improve the yarn for knitting. With shorter-term discontinuities, the effect is even more pronounced. Rewinding with re-waxing can be advantageous in many cases but overwaxing should be avoided as this may lead to further difficulties.

FIGURE 11



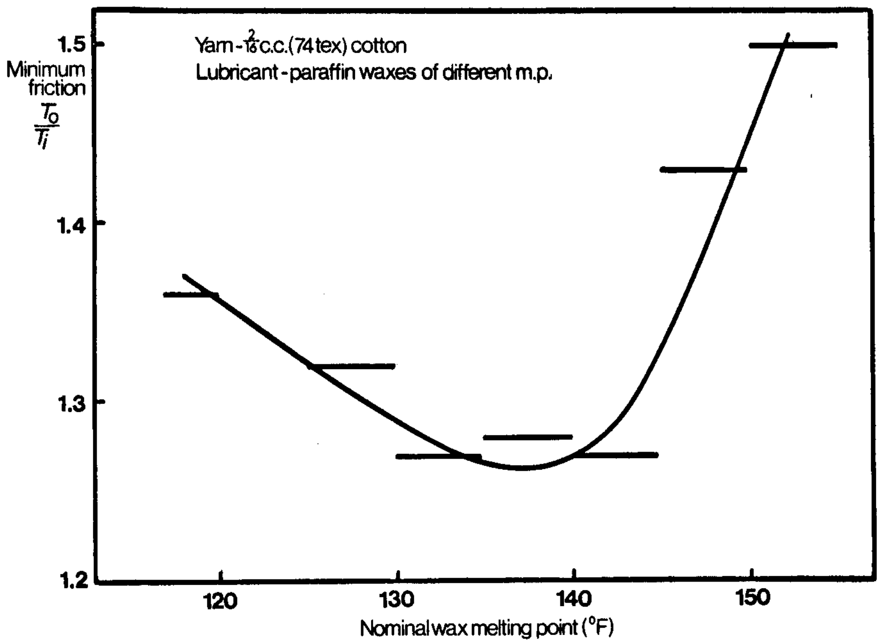
EFFECT OF WAX LOADING ON FREE-RUNNING DISC WAXER ON YARN/METAL FRICTION.

FIGURE 12



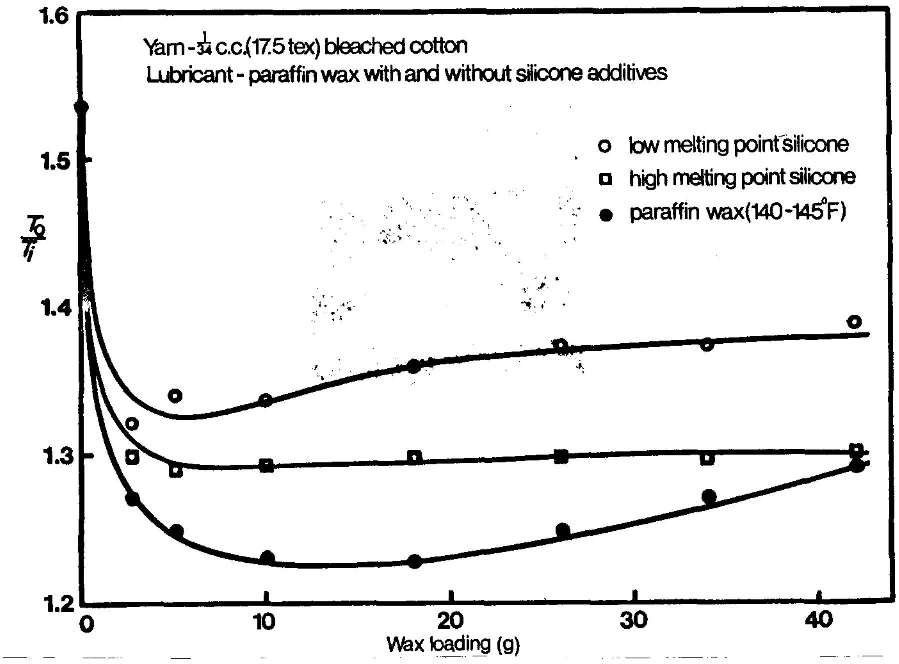
VARIATION OF FRICTION WITH WAX LOADING ON FREE-RUNNING DISC WAXER FOR PARAFFIN WAXES OF DIFFERENT MELTING POINTS.

FIGURE 13



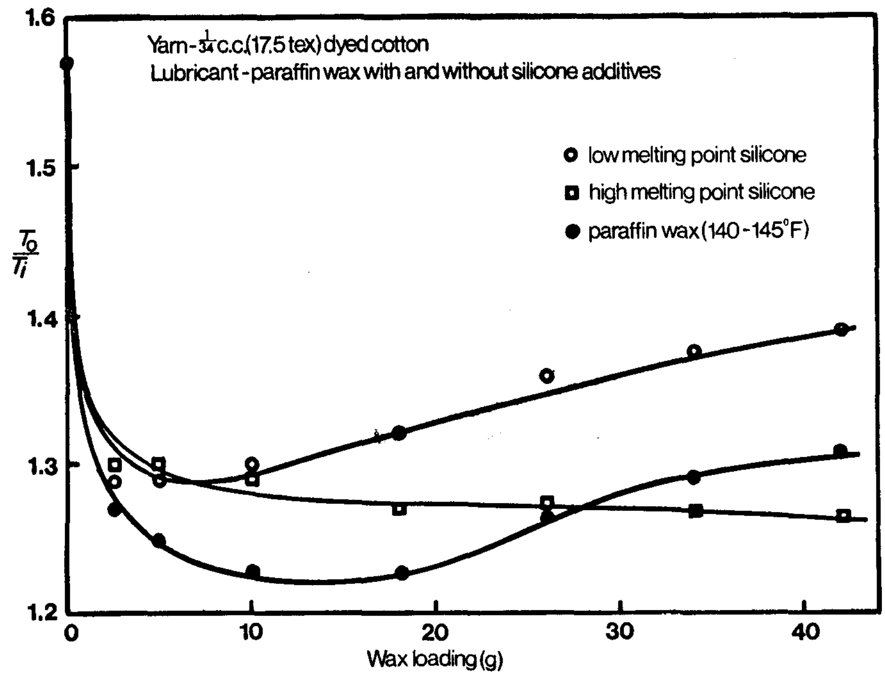
EFFECT OF WAX MELTING POINT ON MINIMUM FRICTION LEVEL.

FIGURE 14



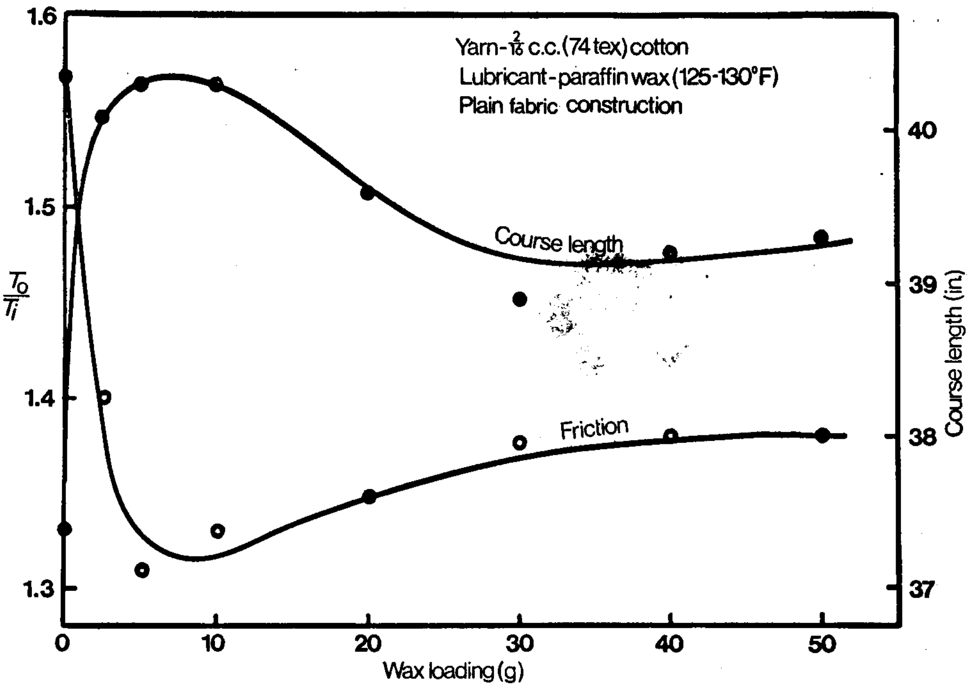
EFFECT OF SILICONE ADDITIVES ON LUBRICATING PROPERTIES OF PARAFFIN WAX.

FIGURE 15



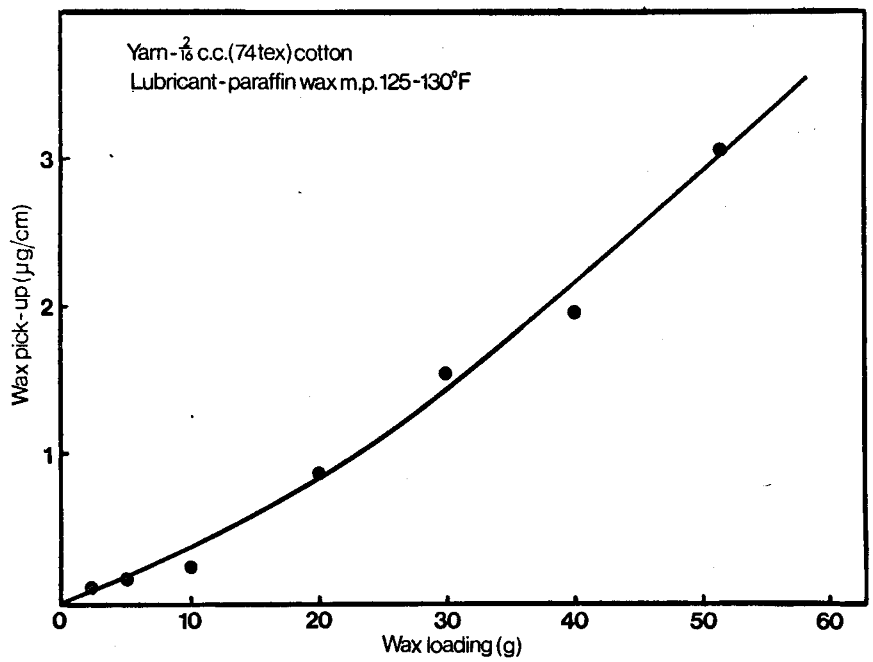
EFFECT OF SILICONE ADDITIVES ON LUBRICATING PROPERTIES OF PARAFFIN WAX.

FIGURE 16



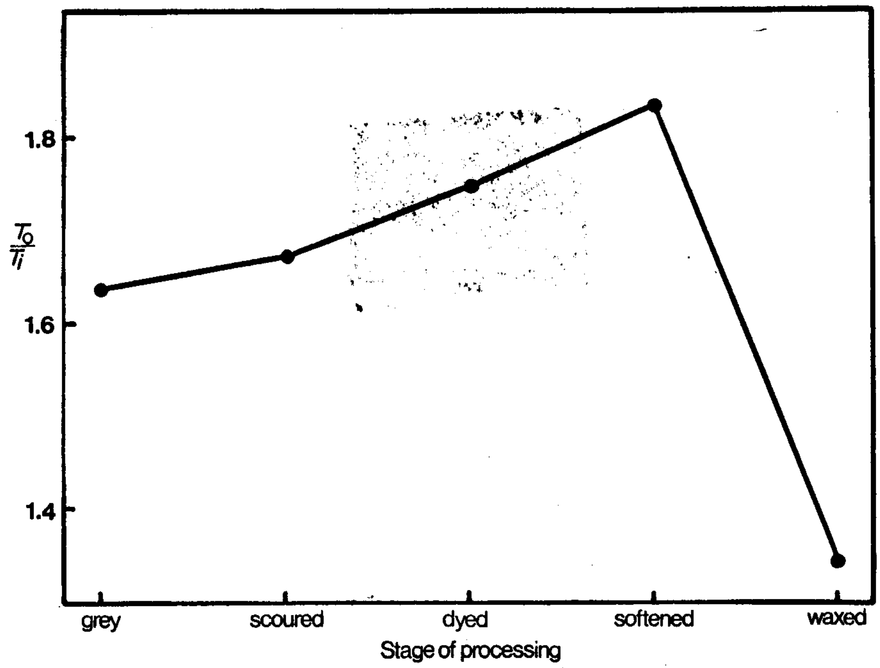
THE EFFECT OF YARN/METAL FRICTION ON KNITTED COURSE LENGTH.

FIGURE 17



EFFECT OF WAX LOADING ON WAX PICK-UP ON FREE-RUNNING DISC WAXER.

FIGURE 18

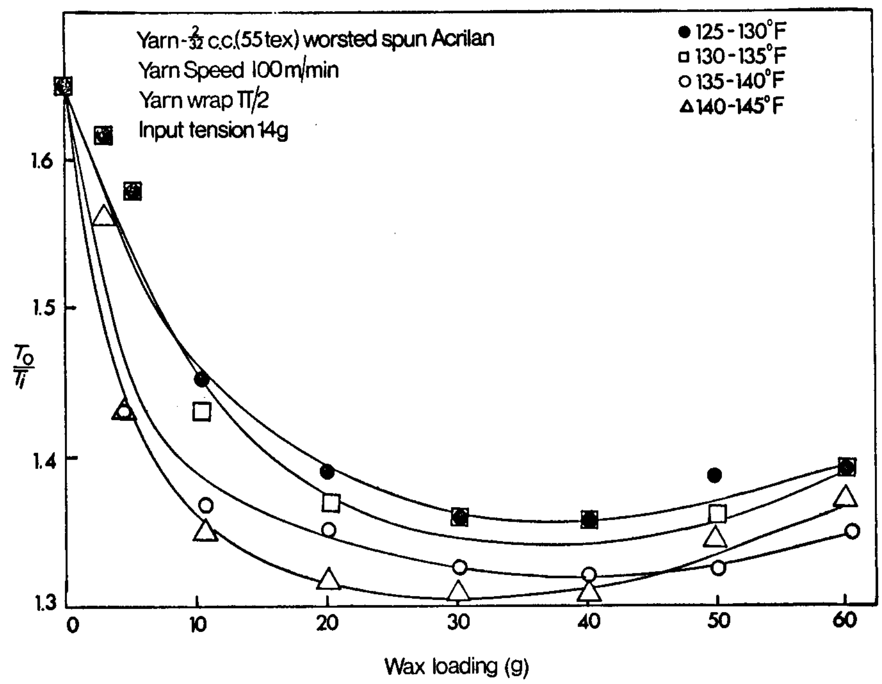


EFECT OF WET PROCESSING ON YARN/METAL FRICTION

It is known that scouring and dyeing may often affect the frictional properties of the yarn. To investigate this effect in cotton yarns, samples were taken at each stage of a factory dyeing process and the yarn/metal friction was measured.

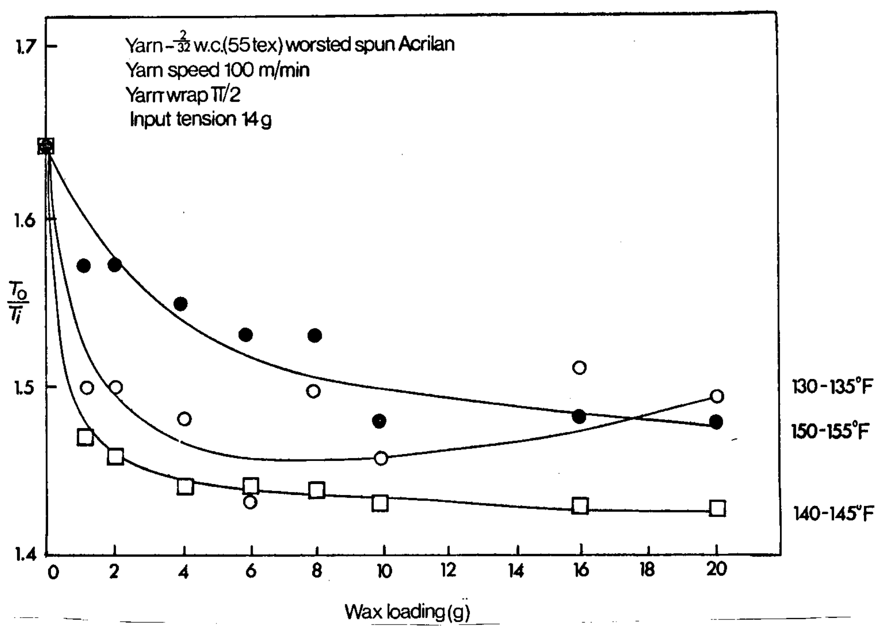
The results, (*Figure 18*) show that, by removing the natural and spinning lubricants, the scouring process increased the friction of the cotton yarns. Dyeing, in this case with an anthraquinone vat dye, gave a further increase in friction. The final stage of wet processing, with a cationic softener, gave yet a further increase in friction. This latter increase may be surprising since such softeners applied in the dyebath are sometimes called lubricants, but this particular softener did not have a yarn/metal lubricating effect. This illustrates the point that while softeners are necessary to give the desired handle in the finished fabric, they are not necessarily a substitute for proper lubrication at the winding stage.

FIGURE 19



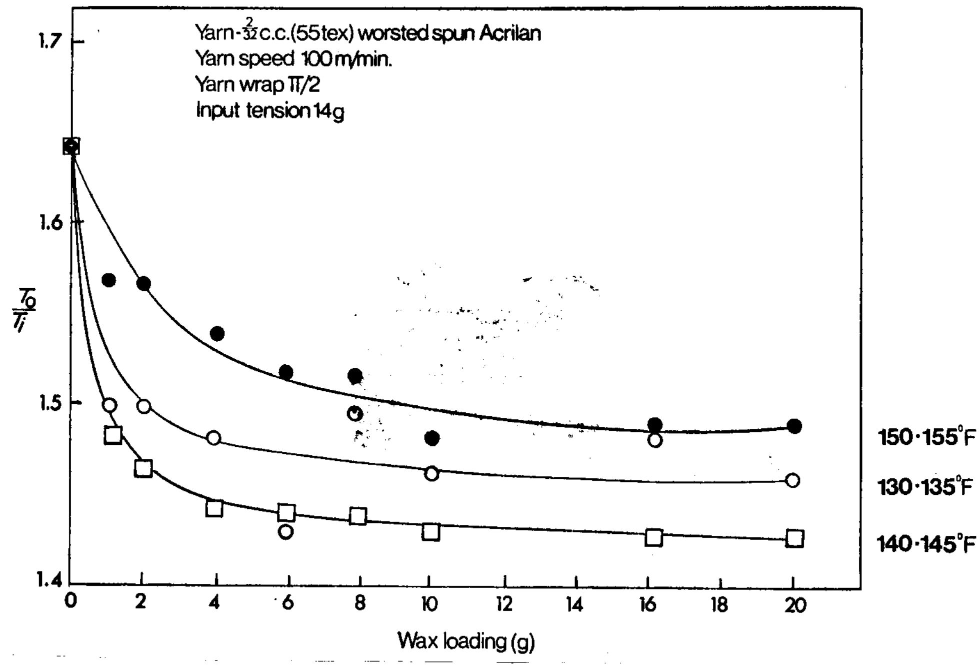
EFFECT OF INCREASING MELTING POINT OF LUBRICANTS.

FIGURE 20



FRICTION OF OILED ACRILAN 16 LUBRICATED ON POWER WAXER WITH WAX DISC ON ONE SIDE.

FIGURE 21



FRICTION OF OILED ACRILAN 16 LUBRICATED ON POWER WAXER WITH WAX DISC ON EACH SIDE

FIGURE 22 - ACRILAN

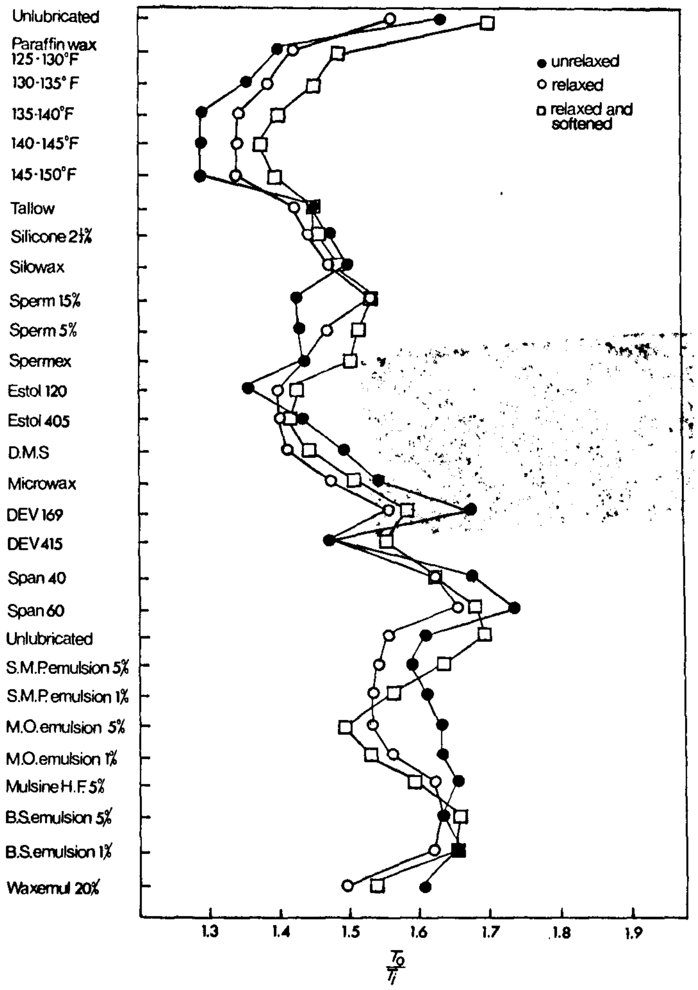


FIGURE 23 - COURTELLE

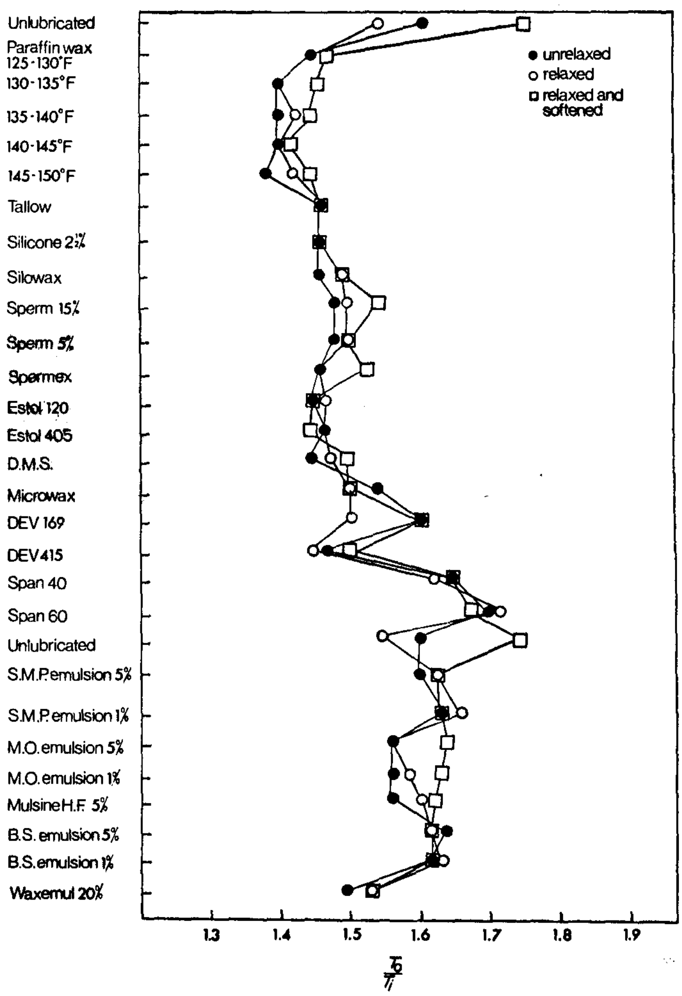
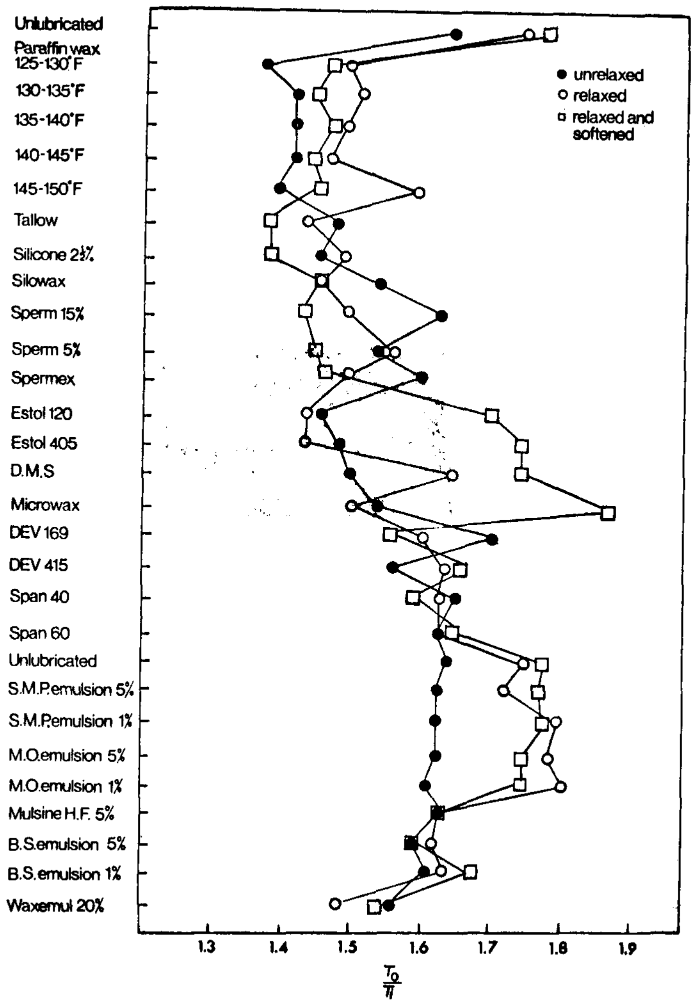
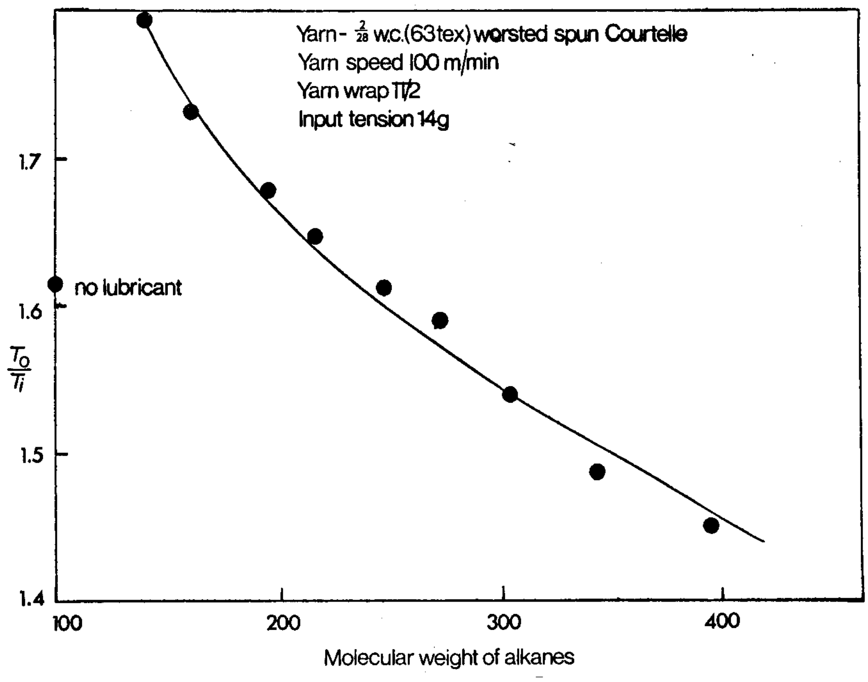


FIGURE 24 - ORLON



FIGURES 22-24 MINIMUM FRICTION VALUES OF ACRYLIC YARNS LUBRICATED WITH DIFFERENT LUBRICANTS.

FIGURE 25



FRICTION OF COURTELLE YARN LUBRICATED WITH PURE N-ALKANES.

During the course of early experiments it was noticed that certain lubricants, instead of lowering yarn/metal friction, actually increased it in some cases to a level higher than that of unlubricated yarn. A similar increase in the friction of nylon filaments treated with n-alkanes (part of the chemical family to which paraffin belongs) has been noted by Rubenstein, who also observed fibre swelling. Since a parallel effect might occur with acrylic fibres, a series of experiments was carried out in which acrylic fibres were treated with the suspected swelling lubricants and the degree of swelling measured.

Swelling with Commercial Lubricants

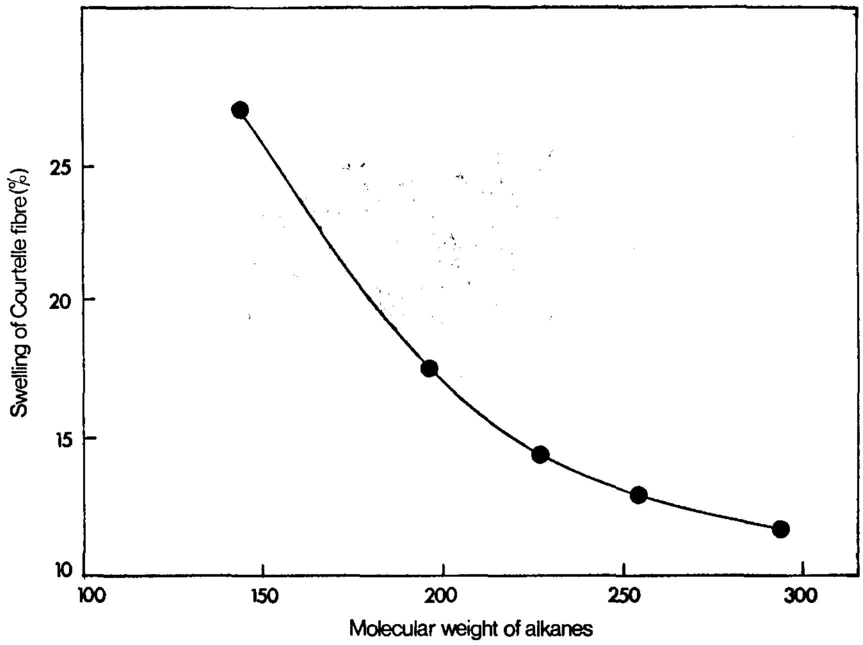
Two of the lubricants which increased friction, DEV 169 and Slack Wax 11 were used. Twenty samples of Courtelle fibre, chosen because of its conveniently round cross-section, were cleaned with trichloroethylene, dried, thickly coated with each of the waxes and left for varying periods of time. They were than rinsed in trichloroethylene and mounted dry on a microscope slide, the fibre diameters before and after treatment were measured. The results, summarised in *Table 4*, indicated that swelling took place and that the maximum effect was obtained within one hour.

Swelling with Pure compounds

Since it is possible for commercial waxes to contain quantities of lower molecular weight alkanes (which are liquid at room temperature) their effect on the lubricating efficiency of solid waxes is of importance.

Pure n-alkanes from n-decane ($C_{10}H_{22}$) to n-eicosane ($C_{20}H_{42}$) identified in *Table 5* were used in the experiments. Washed Courtelle fibres were immersed in the liquids maintained at a temperature of 40 °C for one hour. They were then removed, washed and measured (*Figure 26*).

FIGURE 26

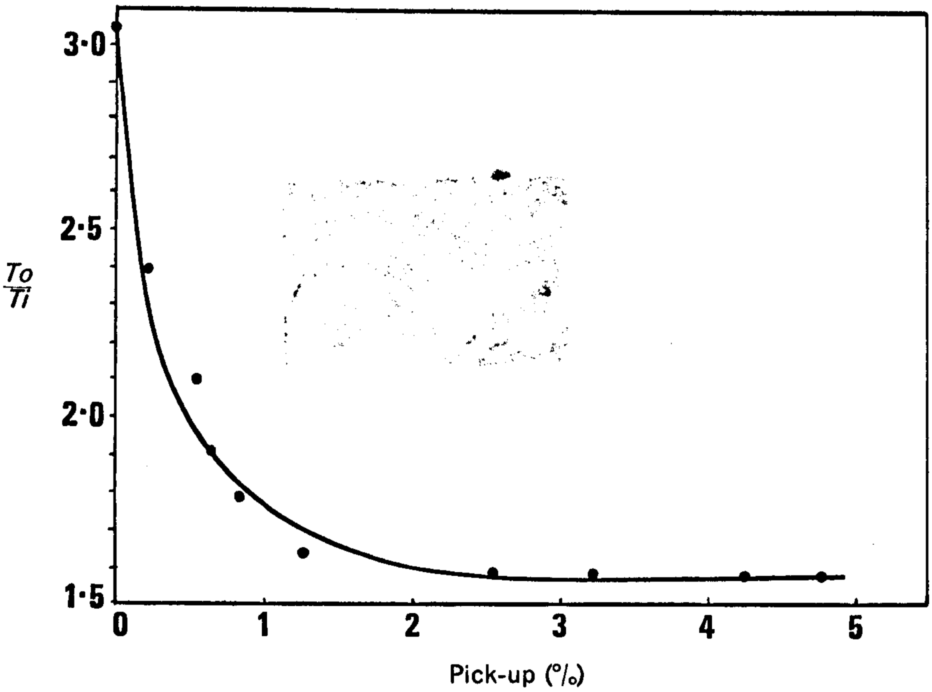


SWELLING OF COURTELLE FIBRES IN N-ALKANES.

Acrylic yarns were lubricated with the alkanes and the frictional characteristics of the resultant yarn measured. The range of n-alkanes was extended to include those normally solid at room temperature from octadecane ($C_{18}H_{38}$) to octacosane ($C_{28}H_{58}$) and these were cast into discs for use on the free-running disc waxer.

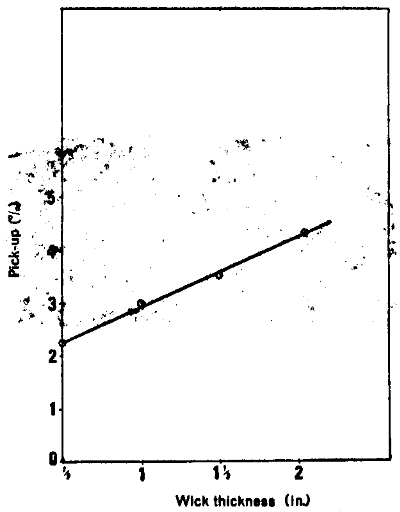
Acrylic yarns were lubricated using these discs under various loadings. The lowest frictional value of the treated yarns from each is plotted against the corresponding molecular weight (*Figure 25*). From these results, it is evident that the presence of low molecular weight n-alkanes affects the frictional characteristics of a paraffin wax and also induces swelling in acrylic fibres. Since, in a paraffin wax which consists of a mixture of alkanes, the melting point, hardness and average molecular weight are proportional, it is apparent from this and earlier work, that the presence of low molecular weight alkanes is undesirable and a well refined wax of high melting point is advantageous.

FIGURE 27



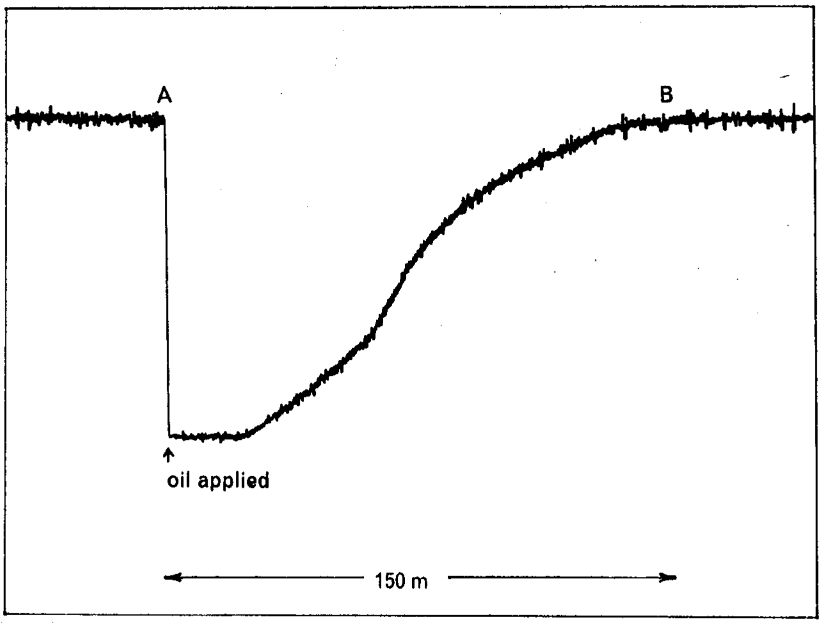
EFFECT OF PICK-UP ON MINIMUM FRICTION

FIGURE 28



EFFECT OF WICK THICKNESS ON PICK-UP.

FIGURE 29

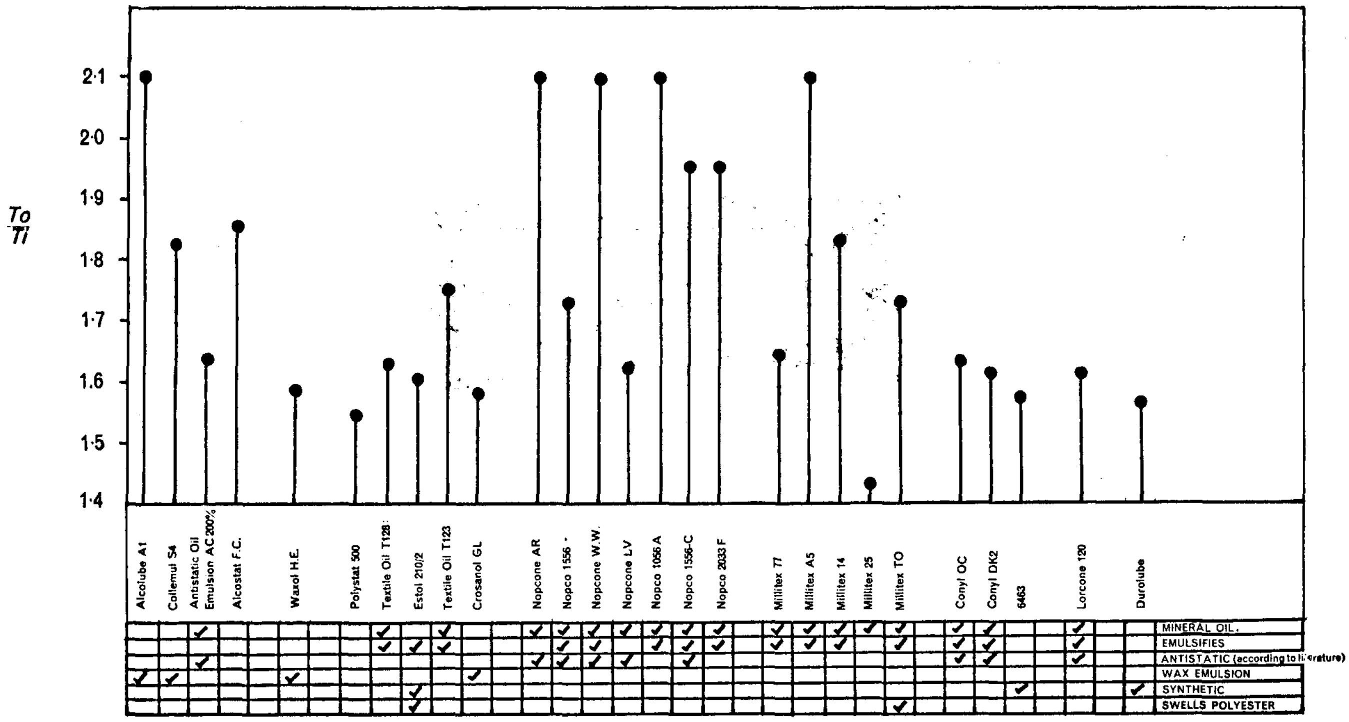


CHANGES IN FRICTION ALONG LENGTH OF UNLUBRICATED YARN WHEN LUBRICANT ADDED.

False-twist nylon 66 yarn was run continuously through the friction tester and a record of the frictional changes was obtained on the potentiometric recorder. At point A, one drop of liquid was dropped onto the yarn.

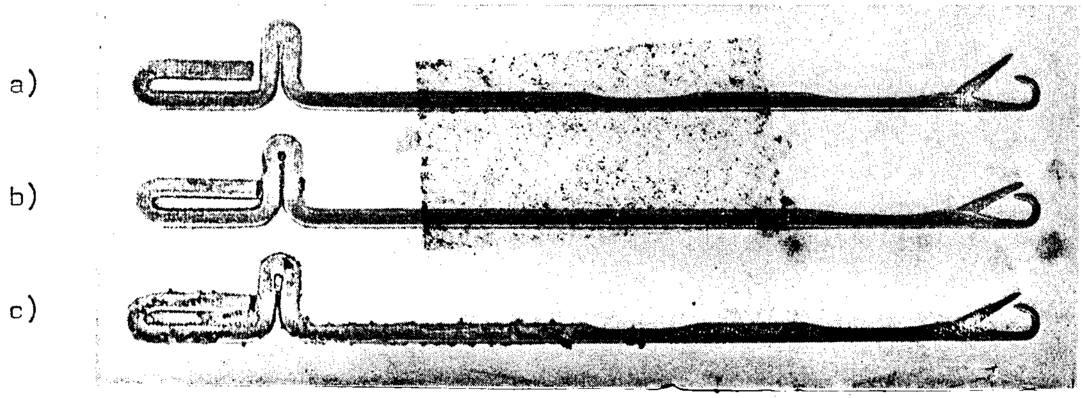
An immediate reduction in the frictional level was observed and from this point there was a slow return to the initial frictional level, at B, about 150 metres of yarn passing through. This indicates that, similarly to staple yarns (*Figure 5*), the lubricant is carried by the yarn to the yarn/metal contacts and is there spread upon the surface to provide the lubricating film. This film is efficient until it is removed by wear during the period AB. A liquid lubricant is worn away much more quickly than a solid, as instanced in the lubrication of staple yarn (*Figure 5*). However, as with the solid lubricant, the deposition of the liquid lubricant on the periphery of the continuous filament yarn is immaterial so long as sufficient is applied in total.

FIGURE 30



MINIMUM FRICTION LEVELS OBTAINED WITH VARIOUS LUBRICANTS ON NYLON AND POLYESTER YARNS.

FIGURE 31



CORROSION OF KNITTING NEEDLES

Whereas most mineral, animal and vegetable oils are, themselves good anti-corrosives, the use of water miscible liquids as lubricants raises the possibility of metal corrosion in the knitting elements.

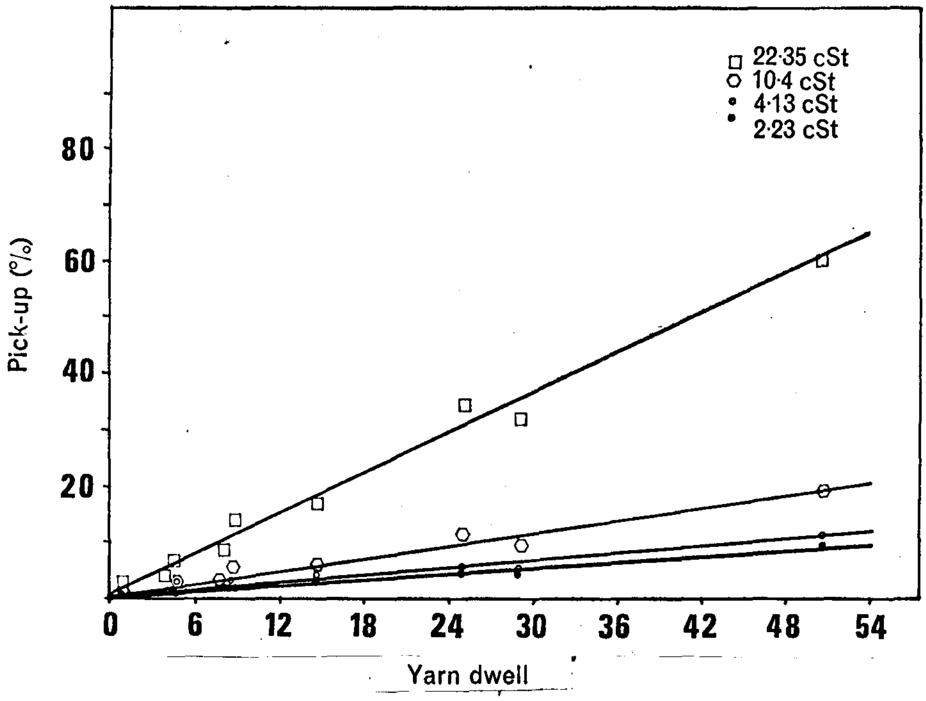
Figure 31 shows the degree of corrosion of a knitting needle immersed for 48 hours in

(a) a mineral oil based lubricant,

(b) a cationic softener plus corrosion inhibitor,

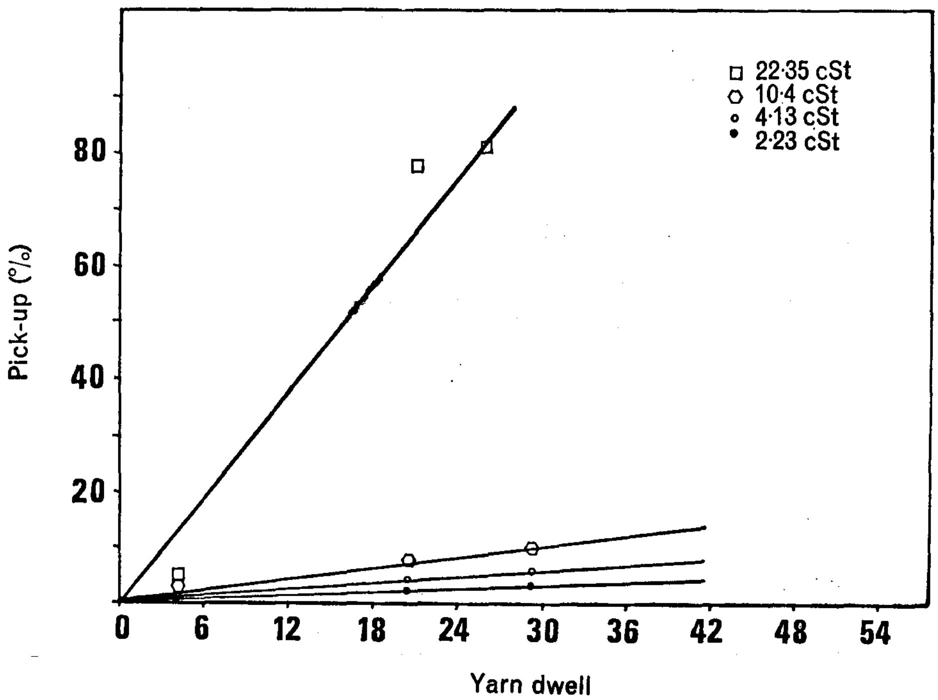
(c) a cationic softener.

FIGURE 32



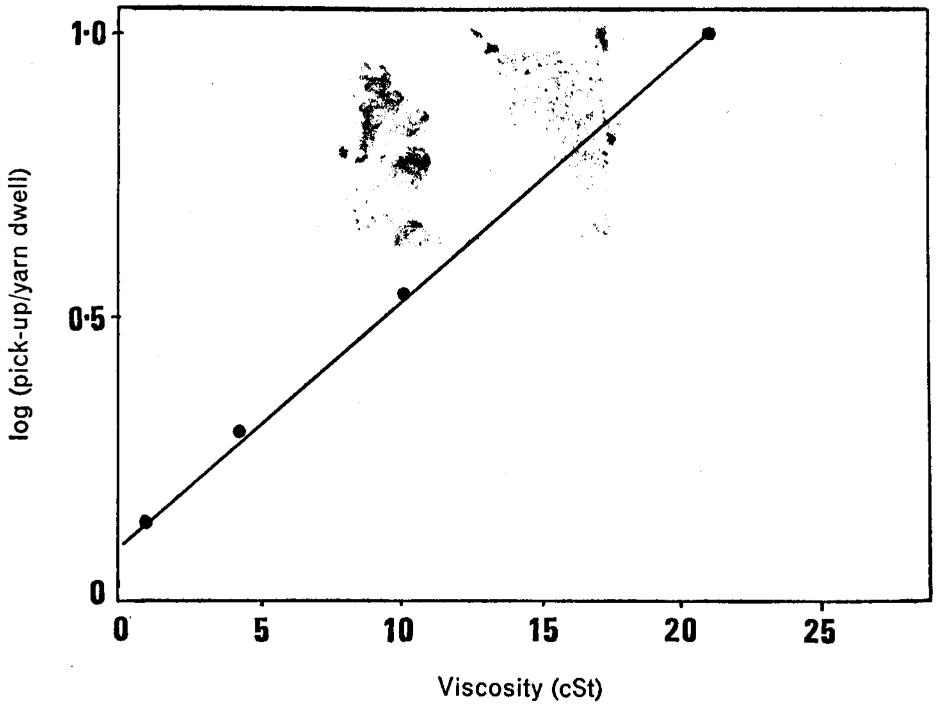
EFFECT OF YARN DWELL ON PICK-UP OF FALSE TWIST NYLON.

FIGURE 33



EFFECT OF YARN DWELL ON PICK-UP OF POLYESTER.

FIGURE 34



EFFECT OF LUBRICANT VISCOSITY ON PICK-UP/YARN DWELL RELATION

Although it has been suggested that thicker oils are more efficient as lubricants than those with lower viscosities, experimental work has not shown this always to be true when the lubrication of yarns is considered. However, oil viscosity has a large part to play in determining the pick-up characteristics of the lubricant when applied to the yarn by roller and trough devices. A high viscosity oil will, with other application conditions the same, give a higher pick-up than one with lower viscosity.

Results of a series of experiments to relate these factors are given in *Figures 32 and 33.* The yarns were Soxhlet extracted to obtain the level of pick-up. These confirmed that increasing yarn dwell and/or the viscosity of the oil increases pick-up. Yarn dwell shows a direct proportionality with pick-up and an approximately linear relation can be obtained by plotting log (pick-up/yarn dwell) against viscosity (*Figure 34*).

Contacts

Lubricant Manufacturers

Fred Gibson & Sons *solid wax discs and wax emulsions*
Station Road, Otley, Yorkshire.

Melior *solid wax discs*
47, Rue de Leers, Roubaux, France

U.K. agents
Texteam Blackburn Limited,
Kay Street, Blackburn, Lances BB2 3BJ

Benjamin R. Vickers & Sons Ltd. *oils and emulsions*
5, Grosvenor Road, Leeds LS6 2EA.

Machinery Manufacturers

Schweiter Engineering Works Ltd.
Horgen, Switzerland.

U.K. agents
A.E. Aspinall (Spinning Equip.) Ltd.
Wrendal House, 2 Whitworth St. West, Manchester M1 5WX.

Scharer Textile Machine Works
Switzerland.

U.K. agents
G.W. Thornton & Sons Ltd
Eden Place, Cheadle, Cheshire. SK8 1AU

W. Schlafhorst & Co
West Germany

U.K. agents
B.L. Engineering Ltd
11 Edward Street, Bradford BD4 7BH, and
Oldham Road, Ashton-under-Lyne.

Officine Savio SpA
Italy

U.K. agents
R. Greenbank & Co. Ltd
Ashton Road, Bardsley, Oldham, Lancs. OL8 3HY

Karl Mayer Textilmaschinenfabrik
5053 Obertshausen

U.K. agents
Karl Mayer - Coltex Ltd
Kings Road, Shepshed, Leicester

Gilbos_pvba
Belgium.

U.K. agents
Robert S. Maynard Ltd
Beech Lane House, Wilmslow, Cheshire

Leesona Texile Machinery Makers
Unity Works, Broadfield.

Yarn Winders

Pear New Mill
Carrington Viyella, Stockport.

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Shirley Institute Bulletin 1971, Vol. 44 No. 6, December.

Shirley Institute Bulletin 1973, No. 5, October

Lubrication Of False Twist Textured Yarns: Geoffrey Redman, Technical Manager, Benjamin R. Vickers.

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2. E. Misca, I Teodorescu and J. Bucurenci. Industria Text, 1972,23 No.9, 537

   Lubrication of wool yarns with paraffin wax most effective providing correct loading on wax ring maintained and wax has melting point in the range 60 - 63 °°C.
3. J.A. Betts and F.N. Hurt: H.A.T.R.A. Research Report No.22, 1972
4. J.A. Betts and F.N. Hurt: H.A.T.R.A. Research Report No.23, 1973
5. J. Lunenschloss and J. Janitza: Textil Praxis, 1971, 26.84,157,226,209,341.

Lubrication of cotton and acrylic fibre yarns also most effective using paraffin wax, although even with optimum lubrication conditions, the yarn friction cannot be reduced to the low values obtained with wool.

6. A. Barella, J.J. Garcia-Dominguez, A.Segura, P. Miro: Bull. Inst. Text. France, 1971, 25, 609.

7. L. Hunter and P.J. Kniger: SAWTRI Technical Report No. 159, 1972.

8. D.F.W. Turpie, P.J. Kniger, L. Hunter: SAWTRI Technical Report No. 160, 1972.

   Dyeing and chemical treatment may affect yarn friction by modifying the surface of the fibres or, indirectly, by the addition of lubricant during processing. With wool and wool blend yarns, tests indicate that the second factor is more important and though oils may contribute to lower yarn friction, in some cases they can adversely affect wax pick-up.

9. J. Lunenschloss and J. Janitza: Textil Praxis 1971, 26, 84, 157, 226, 289, 341

10. B.G. Schuler: Melliand Textilberichte 1972, 53, 1357

11. J.M. Jacob: Ann. Sci. Text. Beiges, 1972, 20, No 1, 88

   Difficulties because of high yarn friction in knitting can also be caused if waxed yarns are stored for long period. Investigations of this problem point out the dangers of storage at high temperatures and suggest that the problems are greatest with underwaxed yarns.

12. 12. Brit. Knit. Industr. 1972, 45, January 75.

   Identification of waxed cones aided by a development by the Shirley Institute of a wax containing a small amount of fluorescent tracer, easily detected under U.V. radiation.

13. W.G. Wolfgang and G. Gradel: Text. Mfr. 1972, July 17.

14. M.J. Hammersley: J. Text Inst. 1971, 62, 286.

   To solve the many problems created by the use of spun yarns on fine gauge knitting machines, treatments additional to normal lubrication may be required. Several treatments have been suggested to improve the knitability of cotton yarns, and with wool yarns, Hammersley has noted that breakages can be significantly reduced by the application of 50% Kerosene to cones of yarn immediately before knitting.

15. N. Cohen Mod. Knitt. Mgmt. 1971, 49, No. 7, 38

16. Book Papers, 13th Canadian Textile Seminar, 1972, 68

17. J.A. Betts and F.N. Hurt: HAT.RA Research Report No 24, 1973

18. R. Buttner and A. Jung: Dtsch. Textiltech. 1971, 21, 493

19. I. 0llenik: Dtsch. Textiltech., 1971, 21, 497

   With continuous filament yarns, paraffin wax can provide effective lubrication, but it is not practicable to apply solid wax from discs because of the cutting action of these yarns. Instead, a wide range of liquid lubricants is used. Comparative tests on such lubricants show the effectiveness of the various additives used in their formulation.

20. Hosiery Trade Journal, 1971, 78, September, 110

   To overcome problems of splashing associated with the application of liquid lubricants, a splashless coning oil has been developed.