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Classification of Fabrics and Fibres

The early humans would have clothed themselves in animal skins; whereas the Egyptians preferred cotton and the Chinese silk.

It is suggested that it was left to the Romans to introduce wool; however, the story of wool began long ago, before recorded history when primitive man first clothed himself in the woolly skins, of the wild sheep he killed for food. He had discovered a durable fabric which gave him what nothing else could give: protection alike from heat and cold, from wind and rain. A versatile fabric which kept him cool in the heat of the day and warm in the cold of the night, which could absorb moisture without feeling wet. Man can never match it. No other material, natural or man-made, has all its qualities.

But man can refine and improve wool. He has done so by selective breeding of sheep and by incorporating in wool fabrics such qualities as shrink resistance, durable creasing and pleating, mothproofing, shower-proofing and stain-proofing.

Science and technology have kept wool in the forefront of fabrics, adapting to modern needs without impairing its virtues. It was woven into cloth here in the Bronze Age, but in historical terms this is comparatively recent. Elsewhere in the world, primitive man had domesticated the sheep in 10,000 BC.

Even before 10,000 BC wool cloth was being spun and woven by the tribes of northern Europe. To spin it they took the wool in one hand and drew it out, twisting it into a thread with the fingers of the other hand. The result was a thick uneven yarn. Later, a crude spindle was developed by fitting a stone or clay ring to the end of a short wooden stick. The ring acted as a flywheel and enabled the drawn-out yarn to be wound on to the spindle. This method of spinning was used for thousands of years and is still used by peasant communities in various parts of the world.

Weaving is the criss-crossing of threads of wool to make cloth. The first loom consisted of a beam from which lengths of yarn (warps) were hung and weighted at the lower end by stones. The `weft' yarn was threaded to and fro across the suspended `warp' yarns in an over-and-under action, like darning a sock. As with spinning, this system was used for thousands of years.

With the industrial revolution humans began to create a new generation of fibres in chemical plants, often imitating the properties of natural fabrics.

When we were sophisticated enough to have professionals washing and cleaning clothes we then had the problem of identifying the different fabrics and fibres.

CLASSIFICATION OF FIBRES

A simple classification can be based on the division of fibres into ‘Natural’ and ‘Man-Made’, being sub-divided as below.

1. Natural Fibres
   - a) Animal (or protein) Fibres
     - i) Wool (the most important), mohair, camel hair, angora (rabbit), etc.
     - ii) Pure silk (from the cocoon of the silkworm).
   - b) Vegetable (or Cellulosic) Fibres
     - i) Seed hairs: Cotton, kapok, etc.
     - ii) Bast fibres (i.e. fibres from the stalks of plants) : Linen (Flax plant).
     - iii) Leaf fibres: Sisal (used in carpets)
   - c) Mineral Fibres

     Asbestos: A fibrous mineral found in many parts of the world notably Canada and South Africa.
2. Man-Made Fibres

   Organic Fibres (“organic”) is a word which in chemical circles is used to mean ‘derived from living matter’.
   - i) Cellulosic: These are fibres made by man from cellulose which is the “body-substance” of plant life living on land from which man has created two types:

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A. Regenerated cellulose such as viscose and rayon.
B. Cellulose derivatives such as cellulose acetate and cellulose triacetate.

ii) Synthetic Resins : Nylon, polyester, acrylics, modacrylics, polyvinyl chloride and elasto-fibres. These are complex chemicals built up from the by-products of coal or oil which themselves are derived from living matter.

b) Inorganic (derived from Non-living matter),

i) Metallic : Thread or yarn of, say, gold, aluminium wire, etc.

ii) Non-metallic : Glass fibres.

For laundry purposes it is seldom that textiles are received for processing constructed from fibres like asbestos, glass fibre or metals (aluminium, gold, etc.). However, in Dry Cleaning, due to the demands of modern fashion, the appearance of clothing is frequently 'enhanced' with metallic threads. (woven or spun into the base fibres comprising the garment.)

Therefore, broadly speaking, for laundry applications, textiles can be split into 4 principle categories, i.e.

ANIMAL	VEGETABLE	REGENERATED	SYNTHETIC
Wool Silk Mohair Cashmere	Cotton Linen Jute Flax Bamboo	Viscose Triacetate (Tricel) Diacetate (Dicel)	Polyester (Terylene) Polyamide (Nylon)

BLENDS AND MIXTURES OF FIBRES: The term 'mixture' at present refers to the use of two different fibres in a fabric when each fibre is present in a separate yarn. For example, a cheap jacket cloth could be made having a cotton warp and wool weft, and is therefore a mixture of wool and cotton.

The term 'blend' refers to mixing the fibres themselves so that the individual yarns contain two or more fibres. For example, a polyester/wool trouser material where the warp and weft yarns may be identical, each having been spun from a blend of 55% polyester staple fibre and 45% wool.

Mixtures and blends are used for a variety of reasons:

a) The cost of a fabric can be reduced by including a proportion of a cheaper fibre with a more expensive fibre.

b) To obtain a particular fabric property, such as wearability, drape or handle, when no individual fibre can produce the desired result, but when two or more fibres can each contribute something so that the final result is nearer to the effect required.

c) Different fibres have a different appearance, lustre or texture and vary in their affinity for dye. Thus decorative and special colour effects can be produced.

It has been customary for many years to combine cotton and wool in certain fabrics. Cotton is relatively cheap and strong whereas wool is more expensive and not very strong, and thus a cotton warp will give added strength to a fabric with a wool weft which provides the texture and colour. Thus, a stronger cheaper fabric can be produced than a fabric of equivalent weight made only of wool.

Mercerised cotton yarns can be incorporated in wool suiting and customised textiles to produce a striping effect or make a logo 'stand-out' via 'jacquard' weaving.

Blends or mixtures of wool with special hair fibres, such as mohair, or spun silk, are normally used to exploit the lustre and handle of the more expensive fibre - and this time it is the turn of the wool to be the cheaper fibre incorporated for reasons of economy. Incorporating less than 10% of fibre in a blend will have little noticeable effect on the texture or handle of the fabric. Only if it has very special and distinctive properties will it begin to make its presence felt at 15%, but at 20% or above properties of the fibre will began to be reflected by appreciable differences in economy, texture and change in strength. Nylon and polyester fibres have excellent strength and abrasion resistance and can be used to strengthen wool fabrics. They are much harder than wool and in large quantities change the appearance and handle of the fabric considerably. Wool is also blended with acrylic fibres which, in handle, are much more like wool than are nylon and polyester, but the strengthening effect of the acrylic fibre is not so great.

From the viewpoint of the manufacturer, blending fibres is not just a simple exercise, but requires careful consideration of the properties of the individual fibres so that the proportions and type(s) of fibres will confer the properties required on the fabric.

FIBRE IDENTIFICATION

Whatever means are employed to create a textile fabric, it will contain one or more fibre types and each type present will retain its own properties. Which means that the nature of the fabric can be altered by affecting a single fibre type no matter how fragile or robust the fabric may appear. It is essential, therefore, to be able to identify fibres and the groups to which they belong in order to assess potential problems and to determine the correct cleaning procedures.

There are several methods of fibre identification, i.e.

a) Burning tests;

b) Microscopic examination:

Solubility tests and Staining techniques can be employed in the laundry but require specialised facilities and seldom employed (methods not discussed in this paper.) There are many other tests which can be used in more specific cases, but these need very specialised staff and equipment.

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a) **Burning Test:** This test is useful in several ways. It will often distinguish between Synthetic and Natural fibre groups, but often poses problems between similar fibres in different groups, (e.g. linen - viscose, rayon, or polyamide / polyester). It should therefore only be used as a guide.

Problems also arise when two or more fibres are present in the fabric, the burning test is not selective enough to determine how many fibre types are present and what they are.

The method is simple enough, a small piece of fabric or even a few threads are inserted into a flame (gas burner or lighter – avoid using matches due to the smell from the burning wood of the match) and three points are noted:

1. How the fibre behaves in the flame.
2. What odours are given off.
3. The appearance of the burned fibre and ash.

1. How the Fibre Behaves

   The manner in which the fibre burns (if it burns at all) should be noted. Cellulosic fibres generally flame and burn quickly, wool generally "bubbles" and burns more slowly. The majority of synthetic fibres melt, but most will burn readily as well. Many fibres display an afterglow effect (cotton is a good example).

2. Odours Emitted

   Most fibres or groups of fibres emit characteristic smells either as they burn or immediately after they are extinguished. Cellulose smells of paper, wool and silk of burning hair or feathers. With Man-Made or synthetic fibres most odours are pungent and considerable experience is necessary to distinguish easily between the types. Blended fibre yarns are difficult to assess by odour.

3. Appearance of Burned Fibres If hard beads are evident then melting or fusing of the fibre substance has occurred. Charring can also determine many naturally occurring fibres dependent on the char type, (e.g. cellulose gives light white/grey dusty ash whereas wool produces a crumbly, black gritty ash). Check for colour change around the burned area if possible. Acrylic fibres often display an orange-yellow halo effect due to heat. Tin weighted silk usually forms a cloth or fibre "skeleton". It is important that experience is built up in order that this test can be applied sensibly, particularly where only a few yarns are available for burning. Ensure the yarns/fibres are taken from each direction (warp and weft) when checking for fibre content.

BURNING TEST FOR FIBRE IDENTIFICATION

A piece of yarn or fabric is held in a naked flame until it begins to burn

NB: *1. Some cotton and viscose fibres are treated to make the fibre flame resistant. These burn slowly, extinguishing on removal from flame, leaving a carbonised residue. A very pungent odour is evident.*

TYPE OF FIBRE	FIBRE	RESULT OF BURNING TEST
Animal	Wool Silk	Does not burn easily. Black ash. Odour of burning feathers.
Vegetable	Cotton Jute	Burns readily without melting. Odour of burning paper.
Regenerated	Acetate Triacetate	Melts, burns rapidly. Not self extinguishing, no soot.
Synthetic	Polyamide Polypropylene Polyester Acrylic PVC, Modacrylic	Melts, burns, goes out. Smells of celery. Melts, burns, goes out. Smells of burning tar. Melts, burns, goes out. Sweet aromatic smell. Burns readily. Sticky residue. Will not burn.

2. Resin finishes on cotton often produce a fishy odour when burnt. (Amine treatment)

b) Microscopic examination:

This can be completed using a simple 1000x magnification microscope and will give a good indication of the fabric fibre composition. However, it should be remebered that, especially with the synthetic fibres, the form and structure of the fibre can be altered to confer differing characteristics to the fabric.

Pre-shrunk (Mercerised/Sanforised) Cotton under the microscope looks like a 'flat twisted ribbon'. It will not have a uniform length or thickness. Cotton that has not been pre-shrunk will be more circular in appearance and have the appearance of a 'hollow tube'.

Wool has a 'scaley' appearance with all of the scales over-lapping each other – and can be likened to 'stacked ice-cream cones'. Wool that has been treated to reduce and/or eliminate shrinkage (felting caused by the interlocking of the scales of the fibre when mechanical action is applied to the fabric) may either be 'coated' with a polymer or have a portion of the scales removed by a bleaching process. In both situations the scales should be visible – but more feint.

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Untreated Polyester looks like a smooth 'glass rod' – but is frequently manufactured with alternative methods to produce a crimped or matt finish.

FROM FIBRE TO FABRIC SUMMARY OF PRODUCTION PROCESS

Staple Yarns

Man soon discovered how to make ropes by twisting vines together, and the step from rope to twine to a yarn for weaving is only a matter of refinement. Try to do it yourself. Take some clean prepared cotton (e.g. cotton wool) in your hand and pinch a few fibres between the finger and thumb of the other hand (moisten your fingers first). Twist the pinch of fibres, pulling away from the mass of cotton wool at the same time. You will probably produce a coarse yarn about five centimetres in length. With practice you should soon be able to produce an arm's length of finer and uniform yarn. The friction between the fibres bind the yarn and the twist brings the fibres closer together which increases the friction thereby making the yarn stronger. Fine yarns require more twist than coarse ones, and smooth fibres need more twist than rough fibres like wool.

This is just what the spinner does, except that he uses mechanical methods. Before spinning, however, much cleansing and preparation of the fibre is necessary. Wool is scoured or washed to remove the grease, sweat and dirt, and may then be oiled with a thin oil to lubricate the fibres in processing. Lanolin is extracted from the wool during the scouring process for use in the pharmaceutical and cosmetic industries. Cotton is not usually washed or scoured at this stage for the natural wax on the cotton is a good lubricant. The wool, cotton, linen or man-made staple fibres, then pass through a series of processes as follows, though not all these processes may be employed:

Carding : To straighten out the fibres and make them lie more or less in one direction.

Combing : To remove short unwanted fibres.

Gilling : To make ropes or slivers of fibres more uniform in thickness and density.

Spinning : To reduce the slivers in size to usable spun yarns. Spinning may be a one-step process (woollen yarns), but may also be a multi-step process (worsted yarns).

Doubling : Twisting individual yarns together for strength or colour effect. If you unravel a piece of cloth and untwist some of the yarns you will probably find them to be 'doubled'.

When we speak of woollen and worsted we think of wool fabrics - but today these words have other meanings and viscose, acetate, rayon, polyester and nylon staple fibres can be spun on the worsted or woollen systems to produce fabrics that look rather like wool fabrics.

Woollen-spun yarns are coarse, non-uniform, rough and hairy, for the processes of combing and gilling have been omitted in their manufacture. Worsted yarns are very uniform in thickness and smooth and non-hairy. Woollen yarns are used to make tweeds and felted (or 'milled') fabrics such as over coatings, blankets, Melton's, etc. Worsted yarns are used for 'worsteds', fine smooth fabrics, hosiery, etc.

Yarns of either type may be made of 'blends' of fibres, (e.g. 50% wool/50% viscose).

Filament Yarns: Making a filament yarn is much easier for it is only necessary to twist long filaments together in a process similar to the doubling described above. This is called 'throwing' in the case of pure silk.

Filament yarns for weaving are usually 'sized' or stiffened to give them greater strength, but hosiery filament yarns may not be sized. They may, however, be treated with other 'finishes', (e.g. an anti-snag finish).

Textured Yarns: Textiles made from filament yarns with the advantage of quick drying and, in some cases, drip-dry properties had problems of comfort and, therefore, ways of putting air spaces inside the fibre were devised. There are many different ways in which textured yarns can be produced, but basically the idea is to put a crimped or curled effect in the filament to induce it to a spring-like formation which results in air gaps which take up moisture from the body. This process is known as 'texturing' or 'bulking'. The texturing process can also improve the drape and handle of the fabric and add bulk and, in the case of nylon, the textured yarns can be made to stretch and recover like elastic.

(a) **Making the fabric:** This can be done by weaving or knitting. Ancient man undoubtedly plaited leaves and twigs to make wattle fences or the walls of his home. By stringing yarns on a frame and threading other yarns over and under with a bone needle he made simple textiles. Weaving by modern standards is very little refined - it has simply been speeded up and mechanised.

The warp yarns (i.e. those in the length of the fabric) are held on a beam large enough to make many yards of fabric. Some of the yarns are lifted up whilst the remainder are kept down. The shuttle carrying the weft yarn then passes between the two sets of warp yarns and leaves a trail of weft. The two sets of warp yarns now change places and the shuttle travels back leaving another trail (pick) of weft. If this one up, one down, motion of the warp yarns (called 'ends) is continued a plain weave fabric ('darning') will be produced. More complicated movements up and down of the warp 'ends' are required to make patterned fabrics.

Ancient man made excellent textiles in this way on primitive looms more than 7,000 years ago. He also learned to knit several thousand years ago, but it was not until the year 1589, that man was able to devise the most simple of knitting machines. Weaving is a primitive art. Knitting is a modern mechanical process and is capable of great development. We now wear knitted suits', for knitting is much more productive and can produce a cheaper fabric.

It is not within the scope of this course to deal thoroughly with the details of fabric production by weaving and knitting. However, the following sections provide information concerning special types of fabrics.

Cut Pile Fabrics: Fabrics with a cut pile may be produced either by weaving or knitting. Velvets and corduroy fabrics are made by weaving then cutting some of the yarns with special knives during the weaving operation. Special knitting techniques which produce large loops on the back of the fabric are available and when these loops are cut the pile is formed.

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Examples of this are seen in the artificial fur fabrics. In contrast, these fabrics are more difficult and more expensive to make than the ordinary woven or knitted materials versus the materials discussed in the following paragraphs.

Bonded Fibre - (Non-woven) Fabrics: This type of fabric is manufactured by taking the fibre of a carding machine and whilst it is still in the form of a mesh it is impregnated with a bonding agent which is then allowed to set. The result is a flat sheet of fibres stuck to each other and running in all directions. Although the use of bonding agents is relatively new, the idea has been used in felt production for many years by building up webs of fibres (mostly wool) into sheets of the required thickness and then causing the fibres to felt together into fabric by heat, moisture, pressure and milling. By using different processes, different types of thickness and consistency of web can be produced which can result in compact fabrics or lofty open fabrics which could be used for padding. Newer techniques with the filaments of Man-Made fibres can be used to produce webs which can be stabilised by heat without the need for any form of bonding agent to hold the fabric together. Non-woven fabrics are the cheapest type of fabric, but are rather stiff with poor draping properties. They do not have an attractive appearance and for these reasons are not popular for apparel. Their main use, therefore, is for fabrics which are not seen. The are used frequently for interlinings as they can be attached to fabrics without sewing. This is done by coating one side of the fabric with a thermoplastic resin which is fused to the outer fabric by the application of a hot iron.

Laminated and Bonded Fabrics: In order to produce warmer fabrics which do not have the weight associated with very thick materials, the idea of combining a fabric with a sheet of plastic foam was tried. It was found that the foam increased the thickness and warmth of the fabric without increasing the weight to any great extent. Thus a cheap method of producing a slightly heavier but thicker material had been developed. Subsequently, it was found that two thin fabrics could be bonded together by means of a layer of adhesive or with a very thin sheet of foam to form in effect a triple layer of fabric. This system offers a cheap and easy method of improving the stability of fabrics, such as single jersey, by bonding two of them together. Loose open-weave fabrics can be made much more stable in wear by bonding them to a light-weight close woven knitted fabric. However, the stability of the combined fabric to cleaning is not improved significantly compared to the component fabrics.

(b) **Fabric finishing processes:** The processes applied to a fabric after its construction are many and varied. The cloth may need a thorough cleansing to remove dirt, sizes or lubricants used in manufacture or it may require bleaching and, of course, if the fibres or yarns from which the fabric was constructed had not already been dyed, then the fabric itself must be coloured by dyeing or printing. However, further development of the appearance and texture of the cloth often takes place. During weaving or knitting many fabrics are constructed in such a way that during hot wet finishing treatments particular effects can be developed, (e.g. the crepe effect in fabrics made from natural fibres and other fabrics with embossed appearances such as pique, cord and seersucker effects). Undesired fibre ends protruding from the surface may be shaved or burned off according to the fibre type to produce smooth fabrics. Where a surface fibre or nap is desired the fabrics are treated to raise the nap by plucking the fibre ends out of the fabric surface with fine wire teeth mounted on rollers (teaselling). Crepe effects and some other effects on Man-Made fibres can be created by embossing using heat and an engraved roller. Various chemical treatments may be given to the fabric during finishing to influence fabrichandle or to create crease-resistant fabrics or to provide durable press effects, (i.e. permanent creases in trousers). Other substances can be applied to make the fabric water and/or stain repellent or to make if flame-resistant.

(c) **Making the garment:** We are now where we started at the beginning of this technical bulletin, using all the various fabrics made from different fibres or from mixtures of fibres to make a garment. When we think of the clean ability of a textile, we tend to think the way the wool or the textile behaves, but much also depends on the construction of the garment and the types of garment accessories used. In particular remember that details given in this course of properties of different fibres are with respect to water with detergents, dry-cleaning solvents and spotting chemicals and valid only for the fibre itself. Dyestuffs on the fibres or fabrics may not withstand a treatment which will leave the fabric undamaged.

Lastly, textiles must be handled in laundering and dry-cleaning according to construction; knitwear must be handled differently from woven goods and it will be important to remember this in future.

RELATIVE HUMIDITY AND TEXTILE REGAIN

1. Relative Humidity

Basically air contains a mixture of oxygen and nitrogen, but it also contains small amounts of other gasses and *WATER VAPOUR*.

Wherever water surfaces (e.g. the sea, lakes, etc.), are exposed to the atmosphere, the vapour pressure of the water molecules enables some water vapour molecules to escape from the surface into the air. Therefore the amount of water vapour which can be carried by the air varies according to the atmospheric pressure and air temperature. However, at any given temperature, the air can only hold a certain quantity of water vapour. Beyond this point the air is said to be SATURATED and the water condenses, falling out of the air as drops of liquid water (rain). The higher the temperature, the more water vapour it can hold before becoming saturated. This explains why condensation takes place on the windows of a warm room in winter. The warm air of the room can hold appreciable amounts of water vapour, but when this air approaches the cold surface of the window, the air cools and it can no longer hold this quantity and the excess water vapour condenses on the glass.

Since warm air can hold more water vapour than cold air, the actual amount held is of little importance. What does matter is how near to saturation the air is.

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This ratio is called the RELATIVE HUMIDITY of the AIR.
It is usually expressed as a percentage and is often written as % RH.

Therefore
RELATIVE HUMIDITY =

$$\frac{\text{WEIGHT OF WATER VAPOUR IN A DEFINITE VOLUME OF AIR}}{\text{WEIGHT OF WATER VAPOUR NEEDED TO SATURATE SAME VOLUME OF AIR AT THE SAME TEMPERATURE}} \times 100$$

Thus, at saturation point % RH = 100 Relative humidity is measured by instruments called *HYGROMETERS* and *PHYSCHROMETERS.*

If air containing some water vapour, but not saturated, is cooled it will eventually reach a temperature at which it will become saturated and condensation begins. This temperature is called DEW POINT. In cold weather the relative humidity out of doors is usually quite high because not much water vapour is needed to saturate the air at low temperature, and so winter days are often misty and damp. Indoors, where rooms are heated, although the actual amount of moisture is about the same, the relative humidity is low because of the higher temperature, and therefore the atmosphere indoors feels much drier, obviously if the heating is turned off the relative humidity quickly rises. In summer, the air temperature is higher and therefore the air is usually “drier”, but if the air temperature drops steeply overnight, the air becomes saturated and a “heavy dew” occurs.

2. Textile Regain

The effect of relative humidity on textiles is very important. Most fibres used in textile manufacture hold some moisture, although they may not feel damp to the touch.

The amount of moisture textile fibres contain depends on two things:

a) The nature of the fibre itself.
b) The % Relative Humidity (RH) of the surrounding atmosphere.

In general terms, the naturally occurring fibres tend to have a larger water-holding capacity than most of the Man-Made fibres.

If a textile is exposed to the atmosphere it reaches a state of equilibrium with the atmosphere. If the RH goes up the textile will absorb water, but if the RH drops, the textile will give up some of its moisture and become drier and lighter.

If the RH is known, the amount of water which a fibre will hold at equilibrium can be determined and is called the REGAIN of the textile. It is usually expressed as a percentage of the absolute dry weight of the fibre.

In order to compare the water holding capabilities of different fibres, the term STANDARD REGAIN is used. This is the amount of moisture which the fibre will hold at equilibrium with an atmosphere at 20ºC and 65% RH, expressed as a percentage of the dry weight of the fibre,

(i.e.) STANDARD REGAIN =

$$\frac{\text{WEIGHT OF MOISTURE WHICH FIBRE WILL HOLD AT 65\% RH AND 20ºC}}{\text{DRY WEIGHT OF SAME FIBRE}} \times 100$$

The water holding capacity of a fibre is important and influences a number of its properties, e.g.

1. Comfort in wear in varying weather conditions.
2. Ease of wash ability and ease of drying.
3. Its susceptibility to static electricity, which can affect the rate of soiling in wear.
4. Effects on drycleanability / launderability with respect to shrinkage or greying.

MOISTURE REGAIN AT 65% RH	
ACETATE	6.5 - 9.0%
ACRYLIC	1.2 - 2.0%
COTTON	7.0 - 8.5%
FLAX	7.0%
NYLON	4.0 - 4.5%
POLYESTER	0.1 - 0.3%
SILK	8.9 - 10.1%
VISCOSE	12.0 - 14.0%
WOOL	14.0 - 16.3%

Relative Humidity and Textile Regain is an important feature when drying textiles because it is easy to over dry, which is expensive in energy and can damage textiles, and modern tumble driers are now fitted with sensors to shut off the heat before the fibre has been dried too much.

For this reason it is vital that the correct classification of textiles is carried out at the sorting stage so that only items with the same fibre content are processed together.

To get the best results only dry items made from the same fibre together.

Cotton towelling can look grey, or yellowed, by over drying, and woollen items also shrink if over dried, or even tumble dried.