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Ministry of Textiles

Textiles Committee

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Chapter 1

BASIC TEXTILE WET PROCESSING TERMS

Absorbency: The ability of one material to take up another material. In textiles, it is the ability of fibre/fabric to take the water quickly.

Acidic: A term describing a material having a pH of less than 7.0 in water

Affinity: Chemical attraction; the tendency of two elements or substances to unite or Combine together, such as fibre and dyestuff. Affinity is usually expressed in units of joules (or calories) per mole.

After-treatment: Any treatment done after fabric production. In dyeing, it refers to treating dyed material in ways to improve properties; in nonwovens, it refers to finishing processes carried out after a web has been formed and bonded. Examples are embossing, creping, softening, printing and dyeing.

Alkaline: A term used to describe a material having a pH greater than 7.0 in water.

Antichlor: A chemical, such as sodium thiosulfate, used to remove excess chlorine after bleaching.

Azoic dyes: The dyes, produced by interaction of a diazotized amine (azoic diazo component) and a coupling component (azoic coupling component).

Basic dyes: A class of positive-ion-carrying dyes known for their brilliant hues. Basic dyes are composed of large-molecule that have a direct affinity for wool and silk and can be applied to cotton with a mordant. These are also known as a cationic dyes.

Auxiliaries: Chemicals used to facilitate and modify the pre-treatment, dyeing, printing and finishing processes.

Bleaching: This is the process in which natural and added impurities in fabrics are removed to obtain clear whites.

Bleeding: Colour rinsing out of a finished garment, yarn, or fibre. Bleeding can be excess dye that was not fully rinsed out or dye that was not properly set on the fibre. Indigo is an exception, see crocking.

Buffering Agent (Buffer): A chemical additive that helps stabilize the dyebath pH.

Carbonizing: A chemical process for eliminating cellulosic material from, synthetic and wool or other animal fibres. The material is reacted with sulfuric acid or hydrogen chloride gas followed by heating. When the material is dry, the carbonized cellulose material is dust-like and can be removed.

Carrier: A product added to a dye-bath to promote the dyeing of hydrophobic fibres and characterized by affinity for, and ability to swell, the fibre.

Caustic Soda: The common name for sodium hydroxide (NaOH)

Cheese: A cylindrical package of yarn wound on a flangeless tube.

Chrome dye: A mordant dye capable of forming a chelate complex with a chromium ion.

Colourant: A colouring matter, a dye or pigment which can produce colour in a substrate like fibre, yarn or fabric.

Colouration: A series of textile operation involved to impart colour in textiles. It embraces dyeing, printing, painting, spraying and preparatory treatment as well.

Colourfastness: Resistance to fading; i.e. the property of a dye to retain its colour when the dyed (or printed) textile material is exposed to conditions or agents such as light, perspiration, atmospheric gases, or washing that can remove or destroy the colour.

Colour strength: A measure of the ability of a dye to impart colour to other materials. Colour strength is evaluated by light absorption in the visible region of the spectrum.

Compatibility: In textile dyeing, propensity of individual dye components in a combination shade to exhaust at similar rates resulting in a build up of shade that is constant, or nearly constant, in hue throughout the dyeing process.

Cross dyeing: A process of dyeing textiles containing fibres having different dye affinities to achieve a multicoloured effect.

Depth of Shade: a percentage describing the amount of dye used proportional to the dry fibre weight, or OWOG. To dye 100 grams of fibre to a 1% DOS, your dye powder would weigh 1% of 100 grams, or 1 gram.

Desizing: The process removal of size materials from greige (gray) fabric to prepare for dyeing.

Detergent: A detergent is a compound or a mixture of compounds, intended to assist cleaning & acts mainly on the oily films that trap dirt particles.

Direct dyes: A class of dyestuffs that are applied directly to the substrate in a neutral or slightly alkaline bath. They produce full shades on cotton and linen without mordanting and can also be applied to rayon, silk and wool. Direct dyes give bright shades but exhibit poor wash fastness.

Disperse dyes: A class of water-insoluble or slightly soluble dyes originally introduced for dyeing cellulose acetate and usually applied from fine aqueous suspensions. Disperse dyes are widely used for dyeing most of the manufactured fibres.

Dyes/dyestuff: Substances that add colour to textiles. They are incorporated into the fibre by chemical reaction, absorption, or dispersion. Dyes may be divided into natural and synthetic types.

Effluent: Waste water released after pretreatment, dyeing & finishing of Textile.

Exhaustion: During wet processing, the ratio at any time between the amount of dye or substance taken up by the substrate and the amount originally available.

Fast or Fastness: A fast colour will not fade due to exposure to light or washing.

Fixation: The process of setting a dye after dyeing of printing, usually by steaming or other heart treatment.

Florescent whitening agent (FWA): Colourant that absorbs near ultraviolet (UV) radiation and re-emits visible (violet-blue) radiation. This causes a yellowish material to which it has been applied to appear whiter.

Hard water: Water described as "hard" is high in dissolved minerals, specifically calcium and magnesium. Hard water is not a health risk, but a nuisance because of mineral buildup on fixtures and poor soap and/or detergent performance.

Heat setting: Heat-setting is a heat treatment by which shape retention, crease resistance, resilience and elasticity are imparted to the fibres. It also brings changes in strength, stretchability, softness, dyeability and sometimes on the colour of the material.

Hydrophilic: Having strong affinity for or the ability to absorb water.

Hydrophobic: Lacking affinity for or the ability to absorb water.

Indigo: Originally a natural blue vat dye extracted from plants, especially the indigofera tinctoria plant. Most indigo dyes today are synthetic. They are frequently used on dungarees and denims.

Ingrain dye: A colourant, which is formed, in situ, in the substrate by the development and coupling of one more intermediate compound. The term was originally used for colourants obtained from oxidation bases and by azoic techniques, but is now reserved for other types of colourant formed in situ.

Inhibitor: A substance that retards or prevents a chemical or physical change. In textiles, it is a chemical agent that is added to prevent fading, degradation, or other undesirable effects.

Leuco dye: A soluble, reduced form of a dye from which the original dye may be regenerated by oxidation.

Liquor ratio: In wet processing the ratio of the weight of liquid used to the weight of goods treated.

Metal-complex dye: A dye having a coordinated metal atom in its molecule. Unless the term metal-complex dye is used in direct association with a particular application class of dye, e.g. metal-complex disperse dye or metal-complex reactive dye, its use is inexact and inadvisable.

Migration: Movement of an added substance (e.g. dye or alkali) from one area to textiles to another. The term commonly used to express the movement of colour from the dyed area to the undyed area of cloth.

Mordant: A chemical used in some textile fibres to provide affinity for dyes. Or a substance, usually a metallic compound, applied to a substrate to form with a dye a complex which is retained by the substrate more firmly than the dye itself.

Mordant dye: A dye that is fixed with a suitable mordant.

Natural Dyes: Dyes made from natural substances, usually from the bark, leaves, roots, flowers, or wood of a plant. There are also insects, notably cochineal and lac that make dyes.

pH: Value indicating the acidity or alkalinity of a material. It is the negative logarithm of the effective hydrogen ion concentration. A pH of 7.0 is neutral; less than 7.0 is acidic; and more than 7.0 is basic.

Pigment: A substance consisting of small particles that is insoluble in the applied medium & is used primarily for its colouring properties.

Reactive dye: A dye that, under suitable conditions, is capable of reacting chemically with a substrate to form a covalent dye-substrate linkage.

Reduction clearing (RC): The removals of unabsorbed disperse dye from the surface of polyester at the end of the dyeing or printing process by treatment in a sodium hydroxide/sodium hydrosulfite bath. A surface-active agent may be employed in the process.

Retarder (Retardants): A chemical that, when added to the dyebath, decreases the rate of dyeing but does not affect the final exhaustion.

Scouring: In textile processing, treatment of textile materials in aqueous or other solutions to remove nature fats, waxes, proteins and other constituents as well as dirt, oil and other impurities.

Shade: A common term loosely used to describe broadly a particular colour or depth, e.g. pale shade, 2% shade, mode shade, fashion shade.

Solubilized sulfur dye: A thiosulfuric acid derivative of a sulfur dye which during dyeing is converted to the substantive alkali-soluble thiol form.

Solubilized vat dye: A water-soluble salt of the sulfuric ester of a leuco vat dye. After application to the fibre the parent vat dye is regenerated by hydrolysis and oxidation.

Solvent dye: A dye which is soluble in organic solvents, but not in water, and is widely used in lacquers, inks, waxes, plastics, soaps, cosmetics, fuels and coloured smokes.

Souring: The term refers to the treatment of textile materials in dilute acid. Its purpose is the neutralization of any alkali that is present.

Sulfur dye: A dye, containing sulfur both as an integral part of the chromophore and in attached polysulfide chains, normally applied in the alkali-soluble reduced (leuco) form from a sodium sulfide solution and subsequently oxidized to the insoluble form in the fibre.

Surfactant: An agent, soluble or dispersible in a liquid, which decreases the surface tension of the liquid contraction of “surface active agent”

Uneven dyeing: A fabric dyeing that shows variations in shade resulting from incorrect processing or dyeing methods or from use of faulty materials.

Vat dyes: A water-insoluble dye, usually containing keto groups, which is normally, applied to the fibre from an alkaline aqueous solution of the reduced enol (Leuco) form which is subsequently oxidized in the fibre to the insoluble form.

Wash fastness: A measure of resistance to fading by laundering. Different dye types are measured at different temperatures.

Wetting agent: It is a chemical substance that increases the spreading & penetrating properties of a liquid by lowering its surface tension that is the tendency of its molecules to adhere to each other.

Wet pick-up: The weight of liquor taken up by a given weight of the fabric after impregnation, spraying, or coating element.

Chapter 2

BRIEF OF ALL WET PROCESSING STAGES

2.1. Sequence of operations in wet processing

Grey cloth
↓
Stitching and Sewing
↓
Shearing and Cropping
↓
Brushing
↓
Singeing
↓
Desizing
↓
Scouring
↓
Bleaching
↓
Dyeing
↓
Printing
↓
Finishing
↓
Inspection
↓
Packing
↓
Baling

2.1.1. Grey Fabric Inspection

After manufacturing fabric it is inspected on an inspection table. It is the process to remove neps, warp end breakage, weft end breakage, holes, spots, etc.

2.1.2. Stitching

Stitching is done to increase the length of the fabric for making suitable for processing. It is done by plain sewing m/c.

2.1.3. Brushing

To remove the dirt, dust, loose fibre & loose ends of the warp & weft threads is known as brushing.

2.1.4. Shearing/Cropping

The process by which the attached ends of the warp & weft thread are removed by cutting by the knives or blades is called shearing. Shearing is done for cotton & cropping for jute.

2.1.5. Singeing

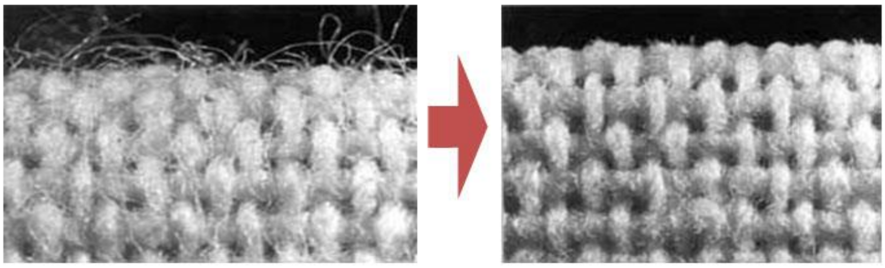
The process by which the protruding / projecting fibres are removed from the fabrics by burning / heat to increase the smoothness of the fabric is called singeing. If required both sides of fabric are singed.

2.1.5.1. Advantages of Singeing

- ✓ Improved end use and wearing properties
- ✓ Clean Surface.
- ✓ Reduced fogginess.
- ✓ Reduced pilling.
- ✓ Reduced Soiling

Singeing usually involves passing/exposing one or both sides of a fabric over a gas flame to burn off the protruding fibres. The temperature of the flame is quite high, hence the fabric is passed over the flame at a high speed such that loose protruding fibres are burnt off but the fabric itself remains undamaged. Heat or the temperature is therefore a key parameter in singeing.

Other methods of singeing include infra-red singeing and heat singeing for thermoplastic fibres. Thermoplastic fibres are harder to singe because they melt and form hard residues on the fabric surface



Un-singed Fabric Singed Fabric

2.1.6. Desizing

Desizing is the process of removal of size material applied on warp threads of a fabric to facilitate the process of weaving. Size forms a stiff, hard and smooth coating on warp yarns to enable them to withstand the cyclic tensions during weaving and reduce breakage

There are three types of Desizing methods namely, Rot steeping, Acid desizing and enzymatic desizing. Enzymatic desizing is more popular and mostly practiced desizing method because it is very safe and does not cause any damage to the fabric. This is one of the important textile pre-treatment possesses to get trouble free dyeing.

2.1.7. Scouring

Scouring is the next process after desizing in which the water insoluble impurities, such as the natural fats and waxes as well as added impurities present in the fabric are removed. Due to the removal of these impurities the absorbency of the fabric increases to the greater extent, which results in efficient further processing.

There are two ways to carry out scouring: 1. Alkali Scouring. 2. Solvent Scouring. Normally, alkali scouring is carried out and the alkali used is sodium hydroxide.

2.1.7.1. Objects of Scouring

- To remove natural fat, wax and oil materials containing in the fabrics without damaging the fibres.
- To accelerate dye and chemical absorption of the fabrics.
- To improve the handle of the goods.
- To remove non-cellulosic substance in case of cotton.

2.1.8. Bleaching

The scouring process of cotton removes waxes and other majority of impurities leaving behind the natural colouring matter. Bleaching completes the purification of fibre by ensuring the complete decolourisation of colouring matter.

Bleaching can be done by oxidative or reductive bleaching agent. The important Oxidative bleaching agents are hydrogen peroxide, sodium or calcium hypochlorite and sodium chlorite. The main reducing agents are Sodium hydrosulphite, sulphoxylates, sodium bisulphites and thioureadioxide increases.

The bleaching process must ensure:

- ✓ A pure and permanent whiteness.
- ✓ Level dyeing properties (There should be no variation in bleaching).
- ✓ Three should not be any loss in tensile strength due to degradation of cellulose.
- ✓ Eco-Friendly bleaching should be preferred.
- ✓ Hydrogen Peroxide is the most widely used bleaching agent.

Bleaching may be carried out using enzymatic bleaching agents. The most popular and preferred bleaching agent is hydrogen peroxide. Hydrogen peroxide bleaching can be done by

i. Batch wise –Crried on Jigger, winch, kier, etc.
ii. Semi-continuous – Pad-batch method
iii. Continuous – Pad –steam-wash

2.1.10. Heat Setting

The purpose of heat setting is to dimensionally stabilize fabrics containing thermoplastic fibres. Polyester and nylon are the principal fibres involved. Blended polyester/cotton fabrics are produced in large quantities. These fabrics may shrink, or otherwise become distorted either during wet processing or in the consumer's hands. Heat setting is a way of reducing or eliminating these undesirable properties.

The process is relatively simple - pass the fabric through a heating zone for a time and at a temperature that resets the thermoplastic fibre's morphology memory. The newly imparted memory allows the fibre to resist fabric distorting forces and provides a way to recover from them. The time and temperature needed for the heat treatment depend on fabric density and previous heat history of the polyester. Time and temperature must exceed that imparted by previous heat treatments. Usually 15 - 90 seconds at temperatures of 180 – 200^{o}C will suffice. The heat setting equipment can be hot air in a stenter frame, or surface contact heat from hot cans. While the process is simple, careful control is required.

2.1.11. Dyeing

Dyeing is the process of colouring fibres, yarns, or fabrics with either natural or synthetic dyes. Textiles are dyed using a wide range of dyestuffs, techniques, and equipment. Dyes used by the textile industry are largely synthetic, typically derived from coal tar and petroleum-based intermediates. Dyes are sold as powders, granules, pastes, and liquid dispersions.

Textiles can be coloured at any of several stages of the manufacturing process so that the following colouring processes are possible:

- stock dyeing
- top dyeing: fibres are shaped in lightly twisted roving before dyeing
- tow dyeing: it consists in dyeing the mono-filament material (called tow) produced during the manufacture of synthetic fibres
- yarn dyeing
- piece (e.g. woven, knitted and tufted cloths) dyeing
- ready-made goods (finished garments, carpet rugs, bathroom-sets, etc.).

Dyes can be used on vegetable, animal or man-made fibres only if they have affinity to them. Textile dyes include acid dyes, used mainly for dyeing wool, silk and nylon and direct or substantive dyes, which have a strong affinity for cellulose fibres. Mordant dyes require the addition of chemical substances, such as salts to give them an affinity for the material being dyed. They are applied to cellulose fibres, wool or silk after such materials have been treated with metal salts.

2.1.11.1. Methods of Dyeing

Similar to scouring and bleaching, dyeing of fabric is carried out by three methods namely;

i. Batch dyeing: jigger, winch, jet, etc.

ii. Semi-continuous: pad batch, pad- roll -steam
iii. Continuous: pad-steam

Dyeing can be performed using continuous or batch processes. In batch dyeing, a certain amount of textile substrate, usually 100 to 1,000 kilograms, is loaded into a dyeing machine and brought to equilibrium, or near equilibrium, with a solution containing the dye. Because the dyes have an affinity for the fibres, the dye molecules leave the dye solution and enter the fibres over a period of minutes to hours, depending on the type of dye and fabric used.

Auxiliary chemicals and controlled dyebath conditions (mainly temperature) accelerate and optimize the action. The dye is fixed in the fibre using heat and/or chemicals, and the tinted textile substrate is washed to remove unfixed dyes and chemicals. Common methods of a batch, or exhaust, dyeing include beam, beck, jet, and jig processing. Pad dyeing can be performed by either batch or continuous processes.

2.1.12. Printing

Printing can be defined as the localized application of dye or pigment in a thickened form to a substrate to generate a pattern or design. In the process of printing colour designs are developed on fabrics by printing with dyes and pigments in paste form with specially designed machines. Printing is used to apply colour only on localized areas.

There are three styles of Printing:

a) Direct printing (which also includes digital and transfer printing)
b) Discharge printing
c) Resist printing.

Direct style of printing: In this type of printing dye is applied onto the fabric by carved block, stencil, screen, engraved roller, etc. The colour is applied to specific areas of a pre-treated textile substrate, which can be white or pre-dyed.

Discharge style of printing: In this method the fabric is dyed and then printed with a chemical that will destroy the colour in designed areas. Some time the base colour is removed and another colour printed in its place.

Resist Style of printing: In this method bleached fabric is printed with a paste containing resisting agent, dried and the fabric is dyed. Special dyeing technique is used in order to avoid the spoiling of resist printed area.

2.1.13. Finishing

Textile Finishing covers an extremely wide range of activities which are performed on textiles before they reach the final customer. The term finishing includes all the mechanical and chemical processes employed commercially to improve the acceptability of the product. Finishing processes might modify a fabric's final appearance, make it softer, or improve elements of its performance. Whichever process is done, textile finishing makes fabric more appealing to the consumer.

Objectives of Finishing

i. To improve appearance of the fabrics
ii. To meet up specific requirements of the fabrics to achieve the final goal.
iii. To increase the life time of durability of the fabric

3.12.1. Classification of Textile Finishes

Textile finishes are classified in different ways

Aesthetic finishes: This type of finishes make change or modify the appearance of the fabric or hand/drape properties of the fabrics.

Functional finishes: This type of finishes changes the internal performance properties of the fabrics.

Finishes also classifies s follows.

Mechanical finishes: This type of finishes also called as dry finishes. This type of finishes also involves specific physical treatment to the fabric surface to cause a change in fabric appearance. Mechanical finishing is considered a dry operation even though moisture and chemicals are often needed to successfully process the fabric. Calendaring, Sanding, Napping, Shearing, Decatising, Sanforizing (pre-shrinking) are the examples of mechanical finishes.

Chemical finishes: This type of finishes usually applied to the fabric by padding followed by curing or drying. Chemical finishing or ‘wet finishing’ involves the addition of chemicals to textiles to achieve a desired result. In chemical finishing, water is used as the medium for applying the chemicals. Heat is used to drive off the water and to activate the chemicals. Softening, Stiffening, Wash-n-wear/durable press/ anti-crease/wrinkle free finishes, Soil release finish, Water repellency, Flame retardency, Antistatic finishes, Anti-pilling finishes and Anti-microbial finishes are examples of the chemical finishes.

2.1.14. Quality Assurance Laboratory

The textile industry has a grave concern for maintaining high quality standards so it establishes rigid systems of inspection before the fabric gets finally packed. It is extremely essential to maintain a reputation of supplying fault free goods. Hence, the fabric undergoes test for product quality at every major stage of processing. The textile material is tested in an equipped laboratory and skilled technicians to maintain product quality. The fabric is instantly rejected if it is not within the specification limits. Modern quality control has been assisted by development of techniques and machines for assessing fabric properties. The automatic testing devices has greatly reduced testing time and cost.

2.1.15. Effluent Treatment Plant

The textile industry generates a lot of toxic effluent during the processing of the fabric which has to be treated before its disposal the strict norms issued by the pollution control boards of respective states to the textile processing industry has helped to curb pollution and combat the menace quite effectively. The effluent process is divided into following process. 1. Physical. 2. Chemical. 3. Biological. 4. Tertiary.

Chapter 3

INTRODUCTION TO WOOL

3.1. What is Wool?

Wool is one of the animal fibres obtained from sheep and some other animals. Animal fibres are the fibres that are naturally obtained from animals. Some animals that live in cold places generally have a thick coat of hair on their body. These coating helps the animals to trap air in it and keep them warm as air is a poor conductor of heat. Air trapped by the hair on the body of animals does not let the warmth to escape from the body. Hence, these thick covering of hair on animal body protect them from cold. Some of the animals are goat, camel, sheep etc.

Wool fibre is the natural hair grown on sheep and is composed of protein substance called as keratin. Wool is composed of carbon, hydrogen, nitrogen and this is the only animal fibre, which contains sulfur in addition. The wool fibres have crimps or curls, which create pockets and give the wool a spongy feel and create insulation for the wearer. The outside surface of the fibre consists of a series of serrated scales, which overlap each other much like the scales of a fish.

3.2. Types of Wool

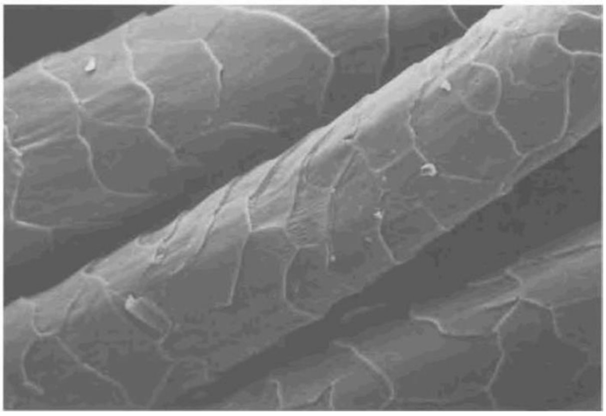
	***Merino:*** Merino sheep, known for having softer coats than others, are the source of this soft and popular wool. It draws moisture away from the skin on one end of the fibre and repels outside moisture on the fibre.
	***Alpaca:*** Supplied by the alpaca, this fine silk fabric is warmenr than sheep wool. Look for it in sweters, coats, gloves, scarves and soeties in upholstery.

	***Mohair:*** Ths lustrous fibre is made fro the hair of the Angora goat. Like merino, mohair fibres are moisture-wicking and good insulators, but they have more sheen which makes fabric made from them more attractive. It's also wears better than sheep's wool.
	***Llama:*** The liama produces a fibre which is naturally glistering. Although they're related to lpacas, llaas have fibres that are coarser and weaker. But they give good warmth without being too heavy.
	***Angora:*** Made from the hair of the hair of the Angora rabit, this heat-retaining fibre is ideal for thermal clothing. As its lightweight as well as soft, its very comfortabel to wear.
	***Cashmere:*** Like mohair, cashmere comes from the hair of goat, the Kashmir goat. Soft to the touch so it's a pleasure to wear, it's also are extremely adept at keeping you warm. Cashmere is the most common type of fine wool used in clothing.
	***Cashgora:*** This hybrid wool comes from a crossbreed of a Cashmere buck and an Angora doe. You'll find it finer than mohair but less so than cashmere.

Chapter 4

COMPOSITION OF WOOL

Wool fibres are extremely complex, highly cross linked keratin proteins made up of 17 different amino acids. The amino acid content and sequence in wool varies with variety of wool. The wool protein chains are joined periodically through the disulphide cross linked cystine, an amino acid that is contained within two adjacent chains. The cross linked protein structure packs and associates to form fibrils, which in turn make up the spindle shaped cortical cells which constitute the cortex or interior of the fibre. The cortex is surrounded by an outer sheath of scale like layer or cuticle, which accounts for the scaled appearance running along the surface of the fibre (shown in figure below).



4.1. Chemical Structure of Wool

Wool is a member of a group of proteins known as keratins. A characteristic feature of hard keratins, such as wool, hair, hooves, horns, claws, beaks and feathers, is a higher concentration of sulphur (in excess of 3%) than is found in soft keratins such as those in skin. The sulphur is present mainly in the form of residues of the amino acid cystine. Wool is composed of 18 amino acids.

The below scheme shows that at neutrality both types of group are fully ionized and the net electrical charge carried by the fibre is zero. This condition is known as the isoelectric state. These ionic bonds are also referred to as ‘salt linkages'. As can be seen from Scheme, the concentration of ionic bonds depends on pH.

$$\underset{\text{acidic}}{H_3N^+\!-\!\text{wool}\!-\!COOH} \;\underset{}{\overset{H^+}{\rightleftharpoons}}\; \underset{\text{isoelectric}}{H_3N^+\!-\!\text{wool}\!-\!COO^-} \;\overset{OH^-}{\rightleftharpoons}\; \underset{\text{basic}}{H_2N\!-\!\text{wool}\!-\!COO^-}$$

Keratin fibres are not chemically homogeneous; they consist of a complex mixture of widely different polypeptides. It has been estimated that wool contains about 170 different types of protein molecule.

4.2. Morphological structure of Wool

The complex morphological structure of fine wool fibres is shown schematically below Figure. Fine wools contain two types of cell: the cells of the external cuticle and those of the internal cortex. Together, these constitute the major part of the mass of clean wool.

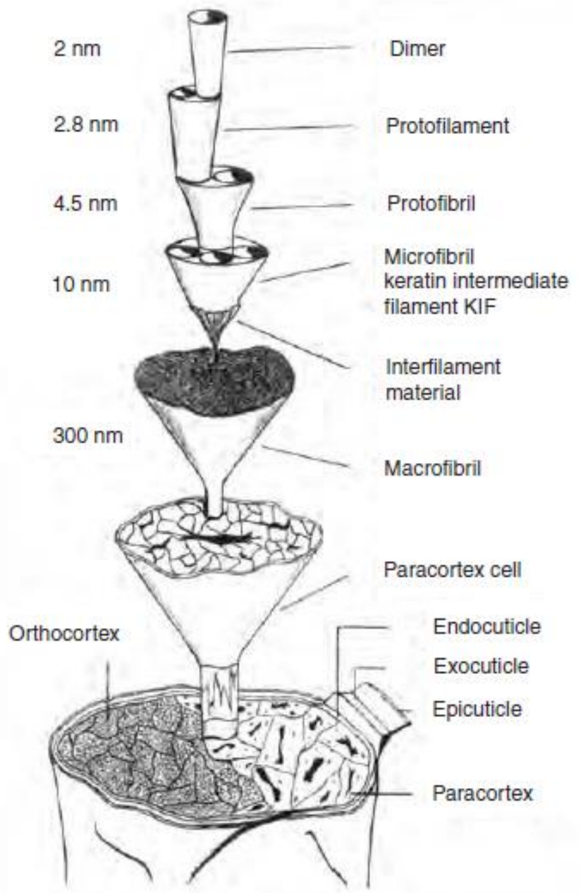


Figure: Morphological structure of fine wool fibres

Cuticle: The cuticle is the layer of overlapping epithelial cells surrounding the wool fibre. There are three cuticles;

i. Epi Cuticle: The epicuticle is the outermost layer covers of the wool fibre.

ii. Exo Cuticle: The overlapping epithelial cell forms the exocuticle.

iii. Endocuticle: The endocuticle is the intermediate connecting layer bonding the epithelial cell of the cortex of wool fibre.

The cuticle cells, or scales, constitute the outermost surface of the wool fibre and are responsible for important properties such as wettability, tactile properties and felting behaviour. Approximately 10% of a fine wool fibre consists of cuticle cells. The amount of each cuticle cell visible on the wool surface varies with fibre diameter; for fine wools the amount of scale overlap is approximately 15%.

Cortex: The cortex – the internal cells-make up 90% of the fibre. There are two main types of cortical cells i.e. ortho-cortical and para-cortical. In finer fibres, these two types of cells from in two distinct halves. The cells expand differently when the absorb moisture, making the fibre bend-this creates the crimp in wool. In coarser fibres, the para-cortical and ortho-chemical cells from more randomly so there’s less crimp. Fibre crimp makes wool fell springy and provides insulation by trapping air.

The cortex, comprising 90% of the fibre, consists of different kinds of cortex cells, ortho- (60–90%) and paracortex cells (40–10%), the latter containing a larger amount of sulphur than the former and hence being tougher and more highly cross-linked. Each cortical cell is composed of 5–20 macrofibrils at the widest point with a diameter of 100–300 nm. The macrofibrils are composed of bundles of 500–800 microfibrils.

Cortical cell: The cortical cells are surrounded and held together by a cell membrane complex, acting similarly to mortar holding bricks together in a wall. The cell membrane complex contains proteins and waxy lipids and runs through the whole fibre and allows easy uptake of dye molecules. The molecules in this region have fairly weak intermolecular bonds, which can break down when exposed to continued abrasion and strong chemicals.

Macro-fibril: Inside the cortical cells, there are long filaments called macro-fibrils. These are made up bundles of even finer filaments called microfibrils, which are surrounded by a matrix region.

Matrix: The matrix consists of high sulphur proteins. This makes wool absorbent because sulphur atoms attract water molecules. Wool can absorb up to 30% of its weight in water and can also absorb and retain large amount dye. This region is also responsible for wool's fire-resistance and anti-static properties.

Micro-fibril: Within the matrix area, there are embedded smaller units called micro-fibrils. The micro-fibrils in the matrix are rather like the steel rods embedded in reinforced concrete to give strength and flexibility. The micro-fibrils contain pairs of twisted molecular chains.

Chapter 5

PROPERTIES OF WOOL

5.1. Physical Properties of Wool

At 2% extension, wool shows 99% recovery, and even at 20% extension a recovery as high as 65% is observed. Wool fibres have excellent resiliency and recover readily from deformation except under high humidities. The stiffness of wool varies according to the source and the diameter of the individual fibres. Wool is little affected by heat up to 150ºC and is a good heat insulator due to its low heat conductivity and bulkiness, which permits air entrapment in wool textile structure.

Colour: The colour of wool fibre could be white, off white, brown and black

Tensile Strength: The tensile strength of wool in dry condition is 1 – 1.7 and 0.8 - 1.6 in wet condition.

Elongation at break: Std. elongation is 25 – 35% and 25 -50% in wet condition.

Elastic recovery: Good

Specific Gravity: Specific gravity is 1.3 – 1.32.

Moisture Regain: 16- - 18%

Resiliency: Excellent

Lustre: Lustre of course fibre is higher than fine fibre.

Effect of Heat: Heat affects wool fibre greatly. Wool becomes weak for heat. It softens when heated or treated with boiling water for long time. At 130ºC it decomposes and chars at 300ºC. Wool does not continue to burn when it is remove from a flame.

Effect of Sunlight: Wool weakens when exposed to sunlight for long periods. The ultraviolet rays cause the disulfide bonds of cysteine to break, which leads to photochemical oxidation. Wool is attacked by short wavelength (300 – 450 nm) UV light, causing slow degradation and yellowing. The main chemical component (Keratin) of wool decomposes under the action of sun light. The sulpher in wool is converted into sulphuric acid. The fibes become discoloured and develop a harsh feel.

5.2. Chemical Properties of Wool

Wool is resistant to attack by acids but is extremely vulnerable to attack by weak bases even at low dilutions. Wool is irreversibly damaged and coloured by dilute oxidizing bleaches such as hypochorite. Reducing agent cause reductive scission of disulfide bonds within the wool. Wool is attached by short wavelength (300-350 nm) ultraviolet light, causing slow degradation and yellowing. On heating, wool degrades and yellowing above 150ºC and chars at 300ºC.

Effect of Acids: Wool is more resistance to acids. Wool is attached by hot concentrated sulphuric acid and decomposes completely. It is in general resistant to mineral acids of all strength even at high temperature though nitric acid tends to cause damage by oxidation. Dilute acids are used for removing cotton from mixture of two fibres; Sulphuric acid is used to remove vegetable matter in the carbonizing process. Wool is only damaged by hot sulphuric acid and nitric acid.

Effect of Alkalis: The chemical nature of wool keratin is such that it is particularly sensitive to alkaline substances. Strong alkaline affect on wool fibre, but weak alkaline does not affect wool. Wool dissolves when boiled in a 5% solution of sodium hydroxide. Weak solutions of sodium carbonates can damage wool when used hot, or for a long period.

Effect of Organic Solvent: Wool does not affect in organic solvents

Effect of Insects: Wool affected by insects.

Effects of Micro Organisms: Wool is affected by mildew if it remains wet for longer time.

Effect of Bleaches: Bleaches that contain chlorine compounds will damage wool. Products with hypochlorite will cause wool to become yellow and dissolve it at room temperature. Various forms of chlorine are used to make ‘unshrinkable wool’, by destroying the scales. This wool is weaker, less elastic and has no feeling properties. Wool is irreversibly damaged and colored by dilute oxidizing bleaches such as hypochlorite.

Reduction: Under controlled conditions, reducing agents can be used to partially reduce the wool.

Effect of perspiration: As already stated, wool is easily deteriorated by alkalis and therefore perspiration which is alkaline will weaken wool as a result of hydrolysis of peptide bonds and amide side chains. Perspiration in general will lead to discoloration.

Dyeing ability: Wool fibre could be dyed by Basic dye, Direct dye and Acid dye. All the wool fibres are not same in characteristics. It varies depending on the wool's country of origin and sheep type.

5.3. End-Use Properties of Wool

Wool verities including merino, Lincoln, Leicester, Sussex, Chevior, Raboullett and Shetland, as well as many others. wool is a fibre of high to moderate luster. Fabric of wool posses a soft to moderate hand and exhibit a good drapability. Wool fibres are highly absorbent and have excellent moisture transmission properties.

The low to moderate strength of wool fibres is compensated for by its good stretch and recovery properties. Wool is fairly abrasion resistant and does not tend to form pills due to its low strength. It resists wrinkling except under warm, moist conditions. Its crease retention is poor unless creases have been set using chemical reducing agents.

Due to its affinity for water, wool is slow drying. Wool may be ironed at 150oC or below without steaming. Wool is self-extinguishing fibre and burns very slowly even in contact with a flame. It has an Limiting Oxygen Index (LOI) of 25.

Wool is extensively used in textile applications, where comfort and aesthetics are important. It is used in men's and women's apparel, outer wear and cold weather clothing, suits, blankets, felts, and carpeting. It is often used in blends with cellulosic and man-made fibres.

5.4. Uses & Application of Wool Fibre

Wool is extensively used in textile applications where comfort and aesthetics are important. Some uses and application of wool fibre are given below –

- ✓ Wool fibre used for clothing, blankets, insulation and upholstery.

- ✓ It is used in men’s and women’s apparel, outer wear and cold weather clothing, suits, blankets, felts and carpeting.
- ✓ It is often used in blends with cellulosic and man-made fibres.
- ✓ It is also used for absorb noise of heavy machinery and stereo speakers.
- ✓ As an animal protein wool, can be used as a soil fertilizers, being a slow release source of nitrogen.

5.4.1. End Uses of Wool Fibres

Alpaca fibres are used for many purposes, including making clothing such as hats, mitts, scarves, gloves. And jumpers. Rugs and toys can also be made from alpaca fibres. Alpaca fleeces is generally used only in the expensive luxury items of textile and apparel

Lama fibres are used in expensive knitted fabrics, jackets, over – coats, and blankets.

Camel hair is used for outer wear and used for under linings

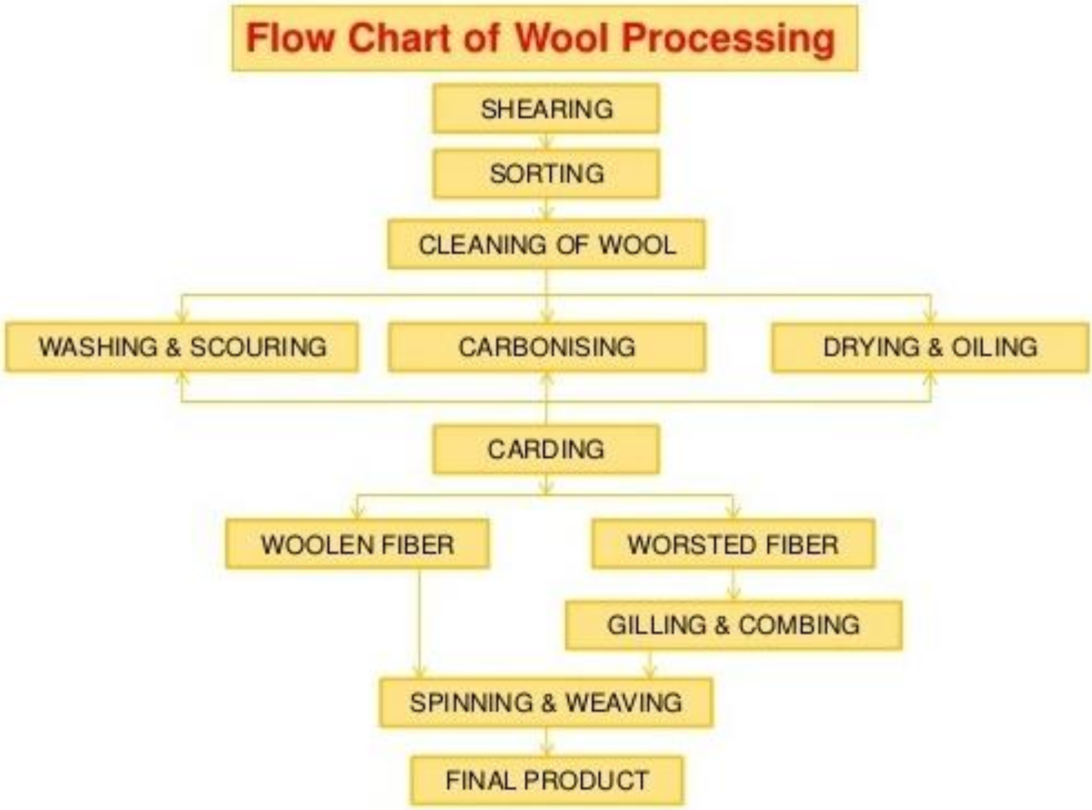
Cashmere is used in luxury applications where a soft, warm, fine fibre with beautiful drape is desired.

Mohair is used for outer – wear.

Chapter 6

WOOL MANUFACTURING PROCESS

6.1. Flow Chart of Wool Processing



6.2. Wool Manufacturing Process

The major steps necessary to process wool from the sheep to the fabric are:

1. Shearing
2. Cleaning and scouring
3. Grading and sorting
4. Carding
5. Drafting and doubling
6. Combing
7. Spinning
8. Weaving
9. Finishing.

6.2.1. Shearing

Sheep are sheared once a year—usually in the springtime. A veteran shearer can shear up to two hundred sheep per day. The fleece recovered from a sheep can weigh between 6 and 18 pounds (2.7 and 8.1 kilograms); as much as possible, the fleece is kept in one piece. While most sheep are still sheared by hand, new technologies have been developed that use computers and sensitive, robot-controlled arms to do the clipping. The fleece can be removed using scissors or mechanical fleece removers.

Picture: Shearing of wool

6.2.2. Grading and sorting

Grading is the breaking up of the fleece based on overall quality. After shearing, the wool is sorted. In sorting, the wool is broken up into sections of different quality fibres, from different parts of the body. The best quality of wool comes from the shoulders and sides of the sheep and is used for clothing; the lesser quality comes from the lower legs and is used to make rugs. In wool grading, high quality does not always mean high durability.

Wool from ewes, rams, and lambs must be sorted from each other and kept separately. Different quality of wool is used for wefts, warps, and piles. Therefore, while sorting wool, factors such as the length of fibres and wool's ability of absorbing dyes should be considered. Wool which is going to be the source of the yarns for pile should be supple, resilient, and soft. The quality of wool varies not only due to the different type of breeds, but it also depends on the geographic location of animals, climatic conditions of the region, the season of shearing, the quality, and composition of fodder.

6.2.3. Cleaning and scouring

Wool taken directly from the sheep is called "raw" or "grease wool." It contains sand, dirt, grease, and dried sweat (called suint); the weight of contaminants accounts for about 30 to 70 percent of the fleece's total weight. The main purpose of scouring is to remove the impurities in wool like dust, dirt, perspiration, and natural oily matter. Without this, further processes are impossible. The process of sequence is carried out in a large machine called the scouring train. This process is carried out in different ways.

To remove these contaminants, the wool is scoured in a series of alkaline baths containing water, soap, and soda ash or a similar alkali. The by products from this process (such as lanolin) are saved and used in a variety of household products. Rollers in the scouring machines squeeze excess water from the fleece, but the fleece is not allowed to dry completely. Following this process, the wool is often treated with oil to give it increased manageability.

6.2.4. Carding

Next, the fibres are passed through a series of metal teeth that straighten and blend them into slivers. Carding also removes residual dirt and other matter left in the fibres. Carded wool intended for worsted yarn is put through gilling and combing, two procedures that remove short fibres and place the longer fibres parallel to each other. From there, the sleeker slivers are compacted and thinned through a process called drawing. Carded wool to be used for woollen yarn is sent directly for spinning.

Photo: Carding of wool

6.2.5. Drafting and Doubling

Drafting is the process of drawing out (or attenuating) a fibrous assembly, such as a sliver, top or roving, to form a thinner strand of fibres. The result is a longer, continuous strand of fibres with a lower linear density than before, i.e. with fewer fibres in the cross-section, and the fibres are straighter and more parallel.

Doubling is the feeding of two or more ends of sliver or roving side-by-side into a drafting zone so that they are combined together and are delivered as one strand. The purpose of doubling is to promote regularity, fibre mixing and fibre alignment, as well as to maximize machine productivity.

6.2.6. Gilling

In worsted top making the card sliver is subjected to a number of preparatory gilling or pin drafting operations prior to combing, in order to straighten and improve the parallelisation of the fibres, to provide further mixing and to reduce the fluctuations in linear density of the sliver. These steps are called preparer gilling. Further gilling steps, called finisher gilling, also occur after combing, to give a highly uniform sliver called top. Combing aligns the leading ends of the fibres, which adversely affects the sliver cohesion and subsequent processing. One of the main objectives of finisher gilling is to again randomize the leading fibre ends by drafting. Finisher gilling also provides further blending, straightening and aligning of the fibres, and the addition of moisture and oil, to produce a top of the required linear density and evenness. The first finisher operation generally involves up to 30 doublings and drafts between 5 and 10, while the second operation involves only 4 or 5 doublings.

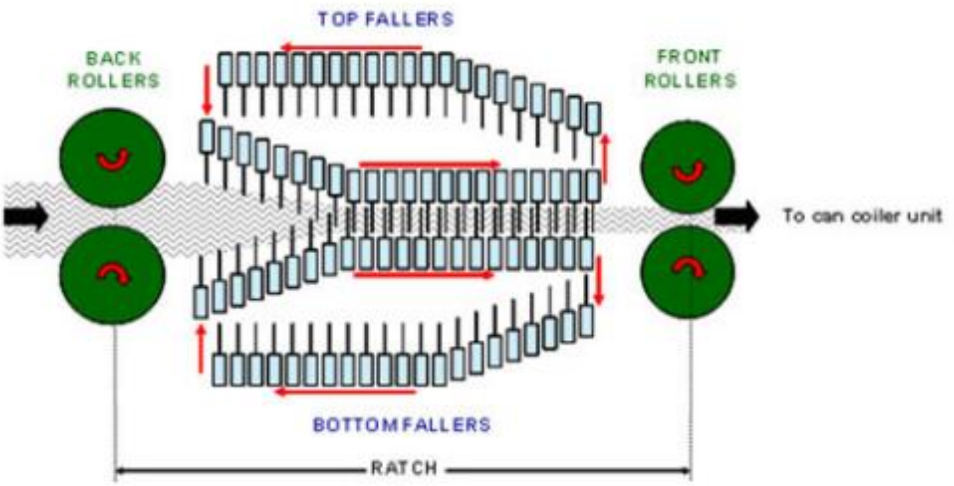


Figure: Principles of Gillbox

Figure: A Gill Faller

Photo: Gillbox

The fallers are metal bars with up to about 100 sharp steel pins projecting from their working surfaces and equally spaced along the length of the bars (shown in above figure). Gill boxes can be equipped with either mechanical or electronic autolevellers and can also be fitted with spraying devices. Adding moisture during high speed gilling is important to achieve the desired regain for subsequent processing. A lubricant (0.1-0.3%) may also be sprayed onto the sliver during the first or second gilling operations to assist in maintaining (or increasing) regain, minimizing static effects and modifying the fibre-to-fibre cohesion. Integrated suction and blowing systems keep the heads clean.

6.2.7. Spinning

After being carded, the wool fibres are spun into yarn. Spinning for woollen yarns is typically done on a mule spinning machine, while worsted yarns can be spun on any number of spinning machines. After the yarn is spun, it is wrapped around bobbins, cones, or commercial drums.

Thread is formed by spinning the fibres together to form one strand of yarn; the strand is spun with two, three, or four other strands. Since the fibres cling and stick to one another, it is fairly easy to join, extend, and spin wool into yarn. Spinning for woollen yarns is typically done on a mule spinning machine, while worsted yarns can be spun on any number of spinning machines. After the yarn is spun, it is wrapped around bobbins, cones, or commercial drums.

6.2.8. Weaving

Next, the wool yarn is woven into fabric. Wool manufacturers use two basic weaves: the plain weave and the twill. Woollen yarns are made into fabric using a plain weave (rarely a twill), which produces a fabric of a somewhat looser weave and a soft surface (due to napping) with little or no luster. The napping often conceals flaws in construction.

Worsted yarns can create fine fabrics with exquisite patterns using a twill weave. The result is a more tightly woven, smooth fabric. Better constructed, worsteds are more durable than woollens and therefore more costly.

6.2.9. Finishing

After weaving, both worsteds and woollens undergo a series of finishing procedures including: fulling (immersing the fabric in water to make the fibres interlock); crabbing (permanently setting the interlock); decating (shrink-proofing); and, occasionally, dyeing. Although wool fibres can be dyed before the carding process, dyeing can also be done after the wool has been woven into fabric.

Chapter 7

PREPARATION OF WOOL FOR DYEING

7.1. Contaminants of Wool

Wool is perceived to be a clean, green, natural fibre. However, raw or 'greasy' wool is contaminated with natural impurities, the type and level depending on the breed of sheep, and the conditions under which the wool is grown. These impurities, which may be up to 40% (or more) by weight, must be washed off before the wool can be used as a textile fibre.

The main contaminants are wool grease, suint and dirt. Wool grease, which is really a wax, is a complex mixture of organic compounds called esters. It is produced by the sebaceous glands in the skin of the sheep and occurs as a stable solid or semi-solid film around the fibre with a melting point around 43^{o}C. While wool grease is insoluble in water, a solution of water and detergent forms an emulsion with wool grease to facilitate its removal from the fibre.

Wool grease is soluble in organic solvents such as ethanol and dichloromethane. The amount of wool grease (or wax) present on the wool depends mostly on the sheep breed, with merinos recording the highest amounts. Crossbred wools, which dominate the New Zealand clip, have substantially less wax.

A third category of contamination acquired by the fleece is termed surface soiling, which includes dirt, dust, faeces and vegetable matter (VM) such as burrs picked up when the sheep is grazing. Traces of dipping compounds (for fly strike or lice) and branding compounds may also be detected.

7.2. Scouring of Wool

The principal objectives of modern wool scouring are to remove all wool contaminants at maximum efficiency, with efficient energy utilisation and with minimum impact on the environment. Quality control objectives for the scoured product are:

- To produce clean wool of consistently good colour, without causing excessive entanglement

- Achieving a specified moisture regain by efficient drying
- Achieving an acceptably low residual grease and dirt content
- To achieve a correct wool pH level (appropriate for subsequent dyeing).

7.3. Methods of Wool Scouring

From chemical point of view, there are various methods of purifying loose wool and these are determined to some extent by the type of material to be cleaned, and the nature and amount of the impurities. The main methods of purification/scouring are: Freezing, Solvent Scouring and Detergent Scouring

7.3.1. Freezing Process

A partial cleaning of wool is possible by freezing technique. The freezing process for removal of dirt and grease consists of passing the wool, after dusting, through low temperature chamber in which the moisture is frozen and the grease solidified.

7.3.2. Solvent Scouring

Solvent scouring consists of opening the wool, dusting and then treating the wool in batches or continuously, using solvent to remove the grease and then scouring the wool in a light soap and soda wash. The used solvent is redistilled and returned to the process and the grease is recovered.

7.3.3. Detergent Scouring

Detergents are cleansing agents and they contain surfactants. The term surfactant is the abbreviated form of surface active agent. Surfactants are used widely in textile processing in many forms, including wetting agents, emulsifiers, and detergents.

At present, wool scouring is most economically done with non-ionic detergents. After emulsion scouring, the separated wool wax is contaminated with detergent and suint. For this reason, the product is called wool grease, as distinct from wool wax.

7.4. Carbonisation of Wool

Carbonisation is performed on woollen items to remove traces of vegetable matter. The most unwanted cellulosic impurities, which remain entangled with raw wool are burrs and broken seeds of various plants. These are to be removed after the scouring process, otherwise these may damage spinning machines like card fabricating and combs. Yams with burrs are difficult to weave and dye evenly.

7.4.1. Wool Carbonisation Process

Sometimes scoured wool contains vegetable impurities that cannot be completely removed through mechanical operations. Sulphuric acid is the chemical substance used for destroying these vegetable particles and the process is called carbonizing. Carbonizing can be carried out on floc/loose fibre and fabric.

7.5. Bleaching of Wool

Wool can be bleached at all stages of processing using conventional processing machine.. Bleaching of wool may be carried out continuously, as in conjunction with raw wool scouring, or batch wise on fibre, yarn and fabric.

Reduction bleaches cause little damage to wool by comparison with oxidative methods. Sodium metabisulphite treatments enhance wool brightness, but the preferred reductive bleaching treatment today utilises stabilised sodium dithionite-based products or, alternatively, thiourea dioxide. Better whiteness can be achieved using formulations based on hydrogen peroxide at the expense of increased damage, particularly to cystene. The most commonly used bleaching agent, hydrogen peroxide, is applied under alkaline conditions using pyrophosphate as pH stabiliser. Stabiliser used in wool bleaching is usually stabilised by sodium pyrophosphate or chemically-related proprietary products. In a typical process wool is bleached with solution containing;

Hydrogen peroxide	15-30 g/l
Tetra sodium pyrophosphate	1-2 g/l

pH of bleaching bath is maintained at about 8.5 and temperature of 50^{o}C.

Wool can be bleached as an ancillary process during raw wool scouring is usually treated with lower levels of hydrogen peroxide than in the batch wise processes mentioned earlier. Typically the final bowl of the wool scouring train would be maintained at 0.5-1.1% peroxide in mildly acidic conditions of pH 6 and temperature not exceeding 40ºC. A modest bleaching effect in conjunction with scouring can also be obtained under reactive conditions. With the last scouring bowl set at about 0.4% sodium metabisuphite concentration and pH of 5.7 – 6.3 the operating temperature should not exceed 55ºC.

Reductive bleaching using stabilised hydrosulphite can be performed as a single process where full bleaching is not required or as a treatment to follow hydrogen peroxide bleaching. In the latter case, reduction bleaching will give an improved, neutral white, generally with better light fastness than that attained with peroxide bleaching alone.

Wool fibres are bleached with 2-3 g/l stabilised hydrogen sulphite at 50-60ºC for 1-2 hrs. Rinse and add 0.5 l/l hydrogen peroxide (35%) to the final rinsing bath to remove residue of sulphurous compounds. If required, a fluorescent whitening agent (FWA) can be added to the reduction bleaching bath.

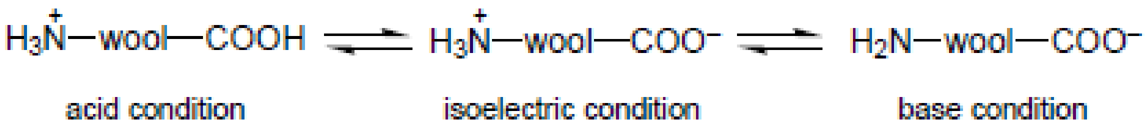
Chapter 8

WOOL DYEING PROCESS

8.1. Mechanism of Dyeing

When wool is dyed with acid dyes, the dye bath normally contains dye anions, hydrogen ions from the acid. When wool is immersed in the dye bath it would be expected that the smallest and most rapidly diffusing ions would be quickly adsorbed while the larger and more slowly diffusing dye anions would follow more slowly. As time proceeds the more slowly diffusing dye anions displace the chloride ions from the wool. By analogy with the behaviour of free amino acids in solution it was assumed that when wool is immersed in water, the amino and carboxyl groups will exist in the ionised or zwitterions form as shown below.

At isoelectric point, the wool carries no net charge because there are equal numbers of positively charged ammonium groups and negatively charged carboxyl anions. As acid is added, hydrogen ions from the acids reacts with carboxylate anions to form carboxylic acid group, leaving the positively charged ammonium groups available to act as 'dye sites' for acid dyes. Under alkaline conditions, on the other hand, hydrogen ions are abstracted from the positively charged amino groups. The carboxyl anions then confer a negatively charge on the substrate.



8.2. Theory of Wool Dyeing

Before explaining any practical dyeing it is important to understand what causes dyes to be attracted to fibres and then to be retained by them. It will then be easier to understand why dyeing procedures have been developed in the way that they have.

8.2.1. Chemical bonding and dyeing

In dyeing there are four different types of forces of attraction or bond at work: ionic bonds, covalent bonds, hydrogen bonding and Van Der Waal's forces.

Ionic bonds: These bonds occur when one atom donates an electron to another and so sets up an electrical attraction between the two. These are primary bonds and are strong. They are effective over large distances and are like the forces of magnetic attraction. Dyes are coloured organic salts and in water a salt divides into two ionic fragments. One ion will be positively charged, the other negative.

Acid dyes split into a coloured negative fraction (dye anion) and an uncoloured positive fraction. Acid dyes will therefore bond with and give colour to fibres that have, or can be induced to have, a positive charge. Wool in acid conditions is such a fibre. Basic dyes do the reverse and so will be attracted to any fibre that has a negative charge. For instance, wool at a pH greater than 4.5 has basic dye sites, the number of which increases as the alkalinity increases.

Covalent bonds: Covalent bonds are also primary bonds and are strong. They are formed by atoms sharing a pair of electrons. In covalent and ionic bonding this is achieved with the filling of the outer electron shells of each atom so it gains the nearest noble gas configuration. A high degree of energy will be required then to break these bonds. The strength, type and degree of chemical bond between a dye and a fibre will control its fastness, in particular its wet and chemical fastness.

Reactive dyes for cotton and wool are the only dyes which use this bonding system as their primary method of attachment. As reactive dyes are primarily acid dyes which have had a reactive group attached, their increased wet-fastness over acid dyes can be solely attributed to the covalent bond.

Hydrogen bonding: Hydrogen bonding is a secondary bonding system and has about one tenth the strength of covalent bonds. Hydrogen bonding comes about in covalent bonds because one of the atoms in the bond is more electro negative than the other. Oxygen and nitrogen are the most electro negative elements and they exert an uneven pull on the electrons of covalent bond atoms. The oxygen being slightly negative, the other atom in the molecule is slightly positive. This allows weak attraction between the negative portion of one molecule and the positive portion of another molecule. The weakness of the hydrogen bond is shown by the generally poor wet fastness of direct dyes and the poor exhaustion shows it has only short range effect.

Van Der Waal's forces: Van Der Waal's forces of attraction, sometimes called mass attraction, is a very complex subject. In its simplest form, molecules may overlap and stick together. The larger the molecule and the more dispersed its electrons, the easier and greater the overlap. Dye molecules are generally large and flat like a sheet of paper so they can overlap the large polymeric fibre molecules to a high degree. Like hydrogen bonds they are weak and can only come into effect over short distances.

Among the four bonding forces listed above, covalent bond is the strongest and Van der Waal's forces bonding is the weakest.

8.3. Factors Affecting the Dyeing of Wool

An activation energy of 10 kcal/mole means dyeing can be done at room temperature 20 kcal/m is 60°C to 80°C, 30 kcal/m is 100°C and 40 kcal/m would require a dyeing temperature of 130° to 140°.

Note that wool only requires 60–80°C, but is commonly dyed at the boil. This is because substantivity reduces with higher temperature so migration can increase, giving levelness. Doing this also reduces exhaustion but as the rate of dyeing is increased a shorter dyeing time results. This improvement in productivity is worth the loss of yield from the dye.

8.3.1. The effect of pH: The pH is the measure of acidity or alkalinity. It is a measure of hydrogen ions in solution, measured on a scale of 0–14; below 7 is acid, above is alkaline. The pH is important in controlling dyeing in two ways. Firstly, dyes themselves may be pH sensitive; in fact, one of the first direct dyes, Congo Red, is now only used as a pH indicator. Secondly, with certain fibres, notably the protein fibres, the pH will control the number of dye sites.

In wool at pH 4.5 the number of dye sites is at a minimum and equally distributed between positive and negative. As the pH becomes more acid more positive dye sites are produced. Going to pH above 4.5 increases the number of negative sites. Wool is dyeable with acid or basic dyes, depending on pH.

8.3.2. The effect of circulation on dyeing: If circulation is slow or uneven, not thoroughly penetrating every area of the fibre, unevenness could result. Slow circulation gives unlevelness because a dye molecule may exhaust from the dye bath and not be replenished. This will give a patchy dyeing with the appearance of light and dark dyed areas. Poor circulation due to machine liquor flow dead spots gives white patches where no dye-charged liquor is flowing. From the dyer's point of view the best type of circulation is high-volume, low-pressure circulation. Dyeing machines are characterised as having either liquor flowing and fabric still, the liquor still and the fabric moving or both fabric and liquor moving.

8.3.3. The effect of auxiliaries: The auxiliaries used in dyeing should be differentiated from the common inorganic chemicals like acids, alkalis and salts. Auxiliaries are more complex, mainly organic molecules. Their function is to improve dispersion, reduce inter-fibre friction, between fibres and between fibres and metals, level or retard dyeings, soften fibres and improve fastness and so on.

8.4. Dyeing Phases

There are five phases in the progress of a dye from the aqueous phase of the dye bath to the solid phase of the fibre.

8.4.1. Approach: The dyes are evenly dispersed or dissolved in the dye bath. Gradually they become more and more aware of where the fibre is located and begin moving towards it.

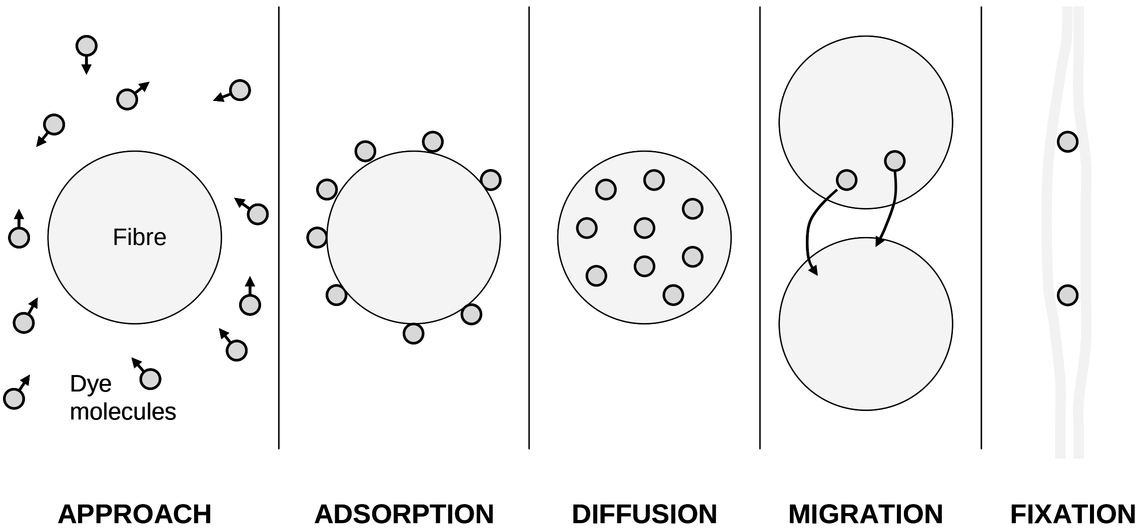
8.4.2. Adsorption**:** Adsorption onto the surface of the fibre. At the sub-microscopic level fibres are very irregular structures and dye becomes lodged on the surface, half in solution and half in the fibre. The adsorption phase is speeded by having more porous fibres, lower crystalinity fibres or undrawn fibres, which don't have a skin/core relationship where the skin is more crystalline then the core.

8.4.3. Penetration: Penetration of the fibre surface by the dye molecule. The process of adsorption and penetration together is called 'absorption'.

8.4.4. Migration: The dye has to penetrate the amorphous structure of the polymer chains and is trying to locate a dye site. If the kinetic energy is low and the substantivity of the dye is high, bonding will occur at the first available dye site and unlevelness could result. More kinetic energy could be supplied to break the bond, but this is only possible if no fibre damage results. If fibre damage would result from increasing the available kinetic energy or if doing a pale dyeing, the dyer will control levelness by controlling the number of dye sites.

8.4.5. Fixation: This is the end of the dyeing process. A stable bonding system of some sort is established and the dyeing is level. In the case of reactive dyes this is virtually irreversible.

The dyeing phases are shown diagrammatically.



8.5. Dyes for Wool

8.5.1. Natural Dyes

Before introduction of synthetic dyes, the most important dyes used for colouring wool were the natural dyes. Natural dyes are extracted from insects or plants. Most of the natural dyes require a mordant, which means that they combine with a metal to produce a different shade with different metal mordants. The aluminium complex is of low light fastness, iron and chrome complexes are light fast but the chrome complex is superior, being both wetfast and lightfast. Examples of sources of natural dyes are Madder, logwood, Fustic, cochineal, etc.

8.5.2. Reactive Dyes

Reactive dyes are applied to wool to enable bright shades with good wet fastness to be obtained. Reactive dyes have also been developed which are based on 1:2 pre-metallised dyes, which, while not as bright, do give excellent wet fastness.

8.5.3. Acid Dyes

Acid dyes are so named because the classical methods of application require them to be applied in strongly acid baths. Now, dyes from the wide range of acid dyes available are grouped according to the acidity of the dye bath required to apply them. Level dyeing or equalising acid dyes are applied at the boil in strong acid and Glauber’s salts. Under these conditions, they give level results, but have only moderate wet fastness properties.

Milling dyes are applied under weakly acid or neutral conditions, and do have good wet fastness properties. Their name comes from their ability to withstand ‘milling’, that is, treatment in a warm, alkaline soap solution under roller pressure for a considerable time. Milling is a treatment used to close up woven structures by felting the wool. Levelness may be harder to obtain on piece goods than with the equalizing acid dyes.

8.5.4. Chrome Dyes

Chrome dyes are very similar to acid dyes, but cannot be used in the same way because of low wet fastness properties. However if the dye is treated with a chrome mordant, it will become insoluble and fixed in the fibre. Fastness is excellent to light and washing, but the shade range is not bright, and is mainly in the tertiary area, that is, browns and greys. Care must be taken to ensure that the chrome complex is formed in the fibre as insoluble particles on the surface can give low rubbing fastness.

8.5.5. Premetallised Dyes

Rather than follow through the relatively complex mordanting process, manufacturers have incorporated chromium into dye complexes, which can be applied as acid dyes.

Two distinct groups exist:

1:1 – premetallised dyes. which are applied from strongly acid solutions. The dyes are level dyeing, have excellent light and wet fastness properties and will withstand light milling treatments

1:2 – premetallised dyes, which are applied in weakly acid conditions, and give excellent wet and light fastness. They also cover damaged wool very well.

8.5.6. Summary of dye properties

Dye type	Shade range	Levelling ability	Wash fastness	pH range	Relative cost
Acid levelling	Bright, pastels	Excellent	Poor	2 – 3.5	Cheap
Acid milling	Bright, pastels	Poor	Very good	6 – 7	More than levelling
1:1 Metal complex	Dull, dark	Good	Good	2	Moderate
1:2 Metal complex	Dull dark	Poor	V. good	6 – 7	More than 1:1
Reactive	Bright pastels	Poor	excellent	3 then 6-7	Expensive

8.6. Auxiliaries Used Before or During Dyeing

8.6.1. Anti-foams

Anti-foams have traditionally been based on silicone oil, which needs careful emulsification. They are very effective as knock-down anti-foams and reduce tangling in high circulation jets. Their disadvantage is in 'cracking out' of emulsion leaving faults that are very difficult to correct on the fabric.

8.6.2. Scouring agents

Scouring agents are surface active agents with a high degree of detergency. They have the ability to remove dirt or other impurities from textiles and hold them in suspension. Positively, negatively and unchanged versions are available depending on fabric type and following dyeing process.

8.6.3. Levelling agents and retarders

Levelling agents and retarders can work on the fibre, the dye or both at the same time. There are positive, negative and uncharged types. Those that works on the dye act to keep it in solution longer, only gradually releasing it to be absorbed by the fibre. The others block dye sites on the fibre, either temporarily or permanently.

8.6.4. Dispersing agents

Dispersing agents are mainly for disperse dyes and are usually negatively charged. Dispersing agents are used in disperse dyeing of polyester to prevent the dyestuff agglomerating and becoming insoluble and crystalising out onto the surface of fibre.

8.6.5. Carriers

Carriers allow dyeing at lower temperatures by promoting swelling of the fibre. Their classic use was in allowing polyester to be dyed at the boil when pressurised machines were not available. As they are usually highly aromatic and somewhat objectionable in open dyeing machines their use is being restricted more and more. Special carriers have been developed for dyeing wool at 80°C.

8.6.6. Exhaustion synchronizer

They work by lengthening the temperature range over which the dyes exhaust. The strike rate is less, without a peak. The strike can start from a lower temperature. They offer reduced dyeing time by allowing faster rates of temperature raising and shorter time at top dyeing temperature, or a lower top dyeing temperature for normal dyeing time. Generally, they also improve dispersion and exhaustion and so aid repeatability of recipes.

8.6.7. Fibre protective agents

Fibre protective agents are used in two different areas. As lubricants they coat fabric fibres, preventing chaffing. In jet dyeing they allow higher fabric speeds, thus allowing more dyeing capacity or shorter dyeing times. In wool dyeing they form protective colloids around the wool to prevent fibre damage from high temperatures.

8.7. Auxiliaries Used After Dyeing

Various after-treating agents are commonly used in dyeing. They are mostly used to increase wet fastness but some improve light fastness. Fixative resins for application to specially developed direct dyes give very good washing fastness and have revived interest in direct dyeing in recent years. Softeners do exactly what their name implies, adding softness to synthetic fibres or replacing natural softness that the dyeing process has stripped off. They may also impart added absorbency and raising or brushing character to the fibre.

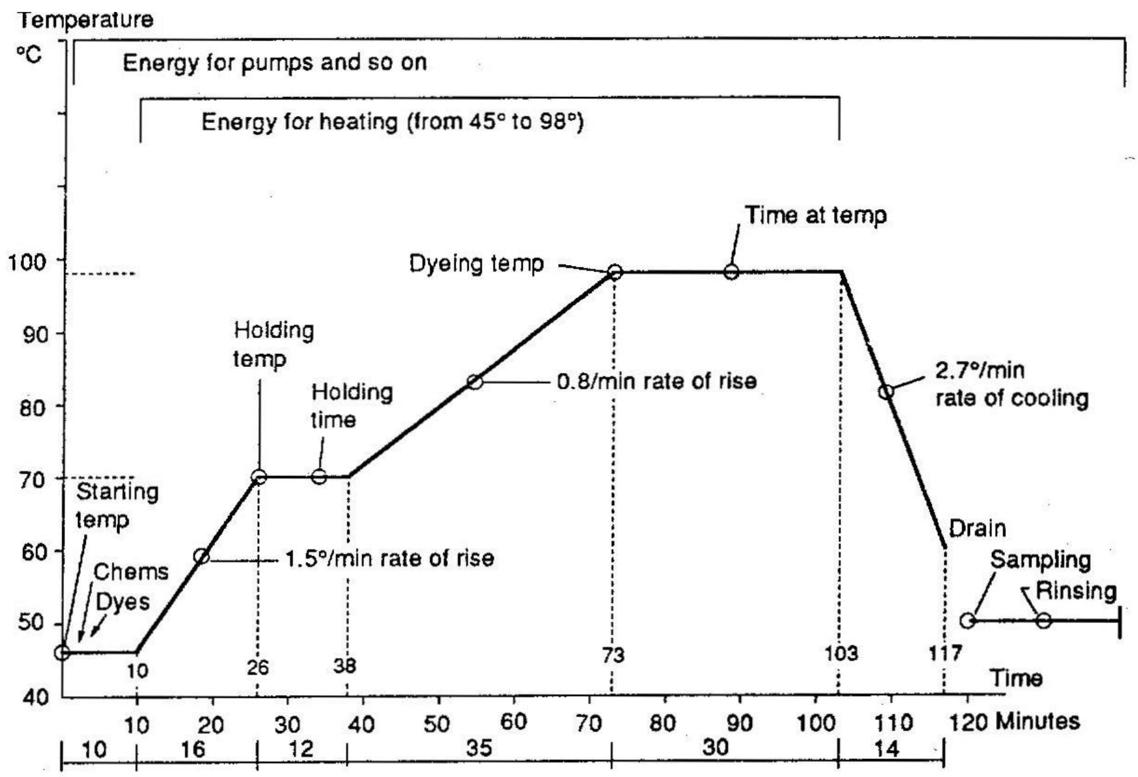
Softeners, like other auxiliaries, sometimes impart undesirable qualities; for example, they can yellow fibres when drying is done and so reduce whiteness of white and can significantly change the shade of pale blues. In general, they reduce the wet fastness of dyeings where the dye or the thermal treatment it receives causes the dye to bleed into the softener over time. Softener, of course, is not as firmly anchored to the fibre as the dye was and so washes out, causing stains.

As stated earlier, wool is dyed with various dyes. The properties of different dyes on wool are different. The dyeing properties are summarised below.

8.8. The Dyeing Process

Textile fibres are composed of large numbers of long-polymer molecules, which are arranged in strands. Between the strands are minute spaces and the average diameter of these spaces is called the *mean pore size*. Large differences occur in the mean pore size of different fibres. Dyeing depends on the dye molecules penetrating into the fibre, and then fixing them within the fibre pores to make the colourfast to washing.

The dyeing process follows a time/temperature profile that is appropriate for the fibre, selected dyestuff and dyeing auxiliaries. A typical time/temperature for the dyeing of wool is given in Figure below.



Graph: Temperature/time profile for wool dyeing

The dyeing sequence usually begins at about 30-45°C with the addition of the dyeing auxiliaries including wetting agent, acid, salt, levelling agent, etc. The liquor is circulated for around 10-15 minutes to allow sufficient time for the dyeing auxiliaries to be uniformly absorbed by the wool. Not only has the wool absorbed the dyeing auxiliaries, but also water from the dye bath, causing the wool to swell. The swelling of the wool fibres makes it much easier for dyestuffs to penetrate the molecular structure of wool.

Once the dyer is satisfied that equilibrium has been reached, the pre-dissolved dyestuff is added to the dye bath from a separate mixing tank. At this stage the dye bath is still at about 30-45°C. The dye molecules now approach and interact with the wool fibre surface, and the temperature of the dye bath is now slowly raised to the boil (100°C) during which time the dye diffuses into the body of the wool fibres.

The dyes may diffuse directly through the scales of the wool into the cortex (transcellular diffusion). Alternatively the dye may diffuse through the intercellular cement between the scales (intercellular diffusion).

Boiling is continued for a further 30-60 minutes, subject to dye type, to achieve migration of the dye both within and between fibres, thereby achieving a level dyeing.

Chapter 9

WOOL DYEING TECHNOLOGY

During the 1980s there have been major developments in wool dyeing machinery, concentrating on innovative design characteristics and automation. This has coincided with a change in the structure of the wool dyeing industry, with a positive trend away from fibre dyeing in loose stock and worsted top and increasing emphasis on late-stage coloration.

Current emphasis is on improving application techniques in package dyeing, piece dyeing and garment dyeing to reduce stock holding and shorten delivery times. Robotic handling is now becoming established in key application areas where high capital investment is linked directly to increased productivity with a reduction in unit labour costs. Automation is now standard in all progressive dye-houses, the objective being increased efficiency and productivity with reduced operator dependency. Environmental issues are now a major consideration in application techniques and machinery design, with emphasis on reduced water consumption and effluent disposal.

Fibre damage in wool dyeing has been reduced in new machinery design, incorporating controlled liquor flow pressure and optimised drying procedures. Radio-frequency technology has become a standard in wool-drying systems based on conveyor belt r.f. dryers, but as yet there have been no major developments in the use of r.f. energy for dye fixation.

Wool may be dyed using a number of different types of dyeing machines and in numerous forms from loose fibre to woven and knitted fabric or even garments. The stage in the manufacturing process at which dyeing is carried out is dependent on a number of factors. Wool can be dyed in different forms, like loose stock dyeing, top dyeing, yarn dyeing, fabric dyeing and garment dyeing.

9.1. Dyeing Process Techniques

Textile dyeing processes fall into one of two basic kinds. These are:

1. *Exhaust* dyeing, and
2. *Continuous* dyeing.

It is usual to dye wool in water, which acts as the solvent vehicle for the colorant, and also is a swelling agent for the fibre.

9.1.1. Exhaust dyeing

In exhaust dyeing the process begins with a set volume of dye liquor and the dye moves from the dye bath liquor on to the fibre in a set time. During that time it diffuses or migrates into the interior of the fibre, and is fixed. The dye liquor, with initially high dye content, becomes gradually exhausted while the dye accumulates in the fibre. The dyes preferred for exhaust dyeing are those with a high affinity for the fibre.

Exhaust dyeing is done with a given liquor ratio. The goods-to-liquor ratio is the weight of goods to be dyed, relative to the volume of dye liquor. This ratio can vary between 1:3 and 1:30 or more. For instance, 1 kg of goods is to be dyed in 3 to 30 litres of dye liquor or more. The amount of dye used in the liquor is calculated from a percentage of the weight of the dry goods.

Exhaust dyeing is used for loose stock, carded sliver, top yarns, and piece goods. Suitable equipment includes circulating liquor machines, winches, jigs, jet dyeing machines, and beam dyeing machines. Small to medium size batches are processed.

9.1.2. Continuous dyeing

In continuous processes, the goods pass through a trough of dye liquor, are sprayed with dye liquor, or have foam dye applied. The important criterion for successful dyeing is the amount of dye liquor that the goods pick up as they pass through the machine. This quantity is a percentage of liquor pick-up. The lower the percentage liquor pick-up, the higher must be the dye concentration in the liquor.

In continuous dyeing, the goods are only in brief contact with the dye liquor. Where possible, the dyer selects dyes that have a low affinity for the fibre. This ensures that a batch of material is dyed to the same shade and depth from beginning to end.

The pick-up is usually quite low, being equivalent to a liquor ratio of 1:1 or less and this leads to substantial savings in water, energy and effluent costs. The fabric, which has become impregnated with dye, is then passed through a steamer to fix the dye to the fabric, followed by washing off.

Continuous methods are mainly used for piece dyeing large lengths of fabric for mass produced articles, such as carpets and are rarely employed for the dyeing of wool fabrics. Therefore they will not be considered further here.

9.2. Stages at Which Wool can be Dyed

Textiles can be dyed at various stages of processing. The decision as to the kind of equipment in which the material is to be dyed depends on the stage of processing and the nature of the fibre.

Loose stock, such as loose wool, and other forms of loose fibre, is dyed in circulating liquor machines. The loose fibres are packed into perforated containers that are lowered into the vessel. This method of dyeing is also known as pack dyeing.

Although yarn hanks can be dyed like loose stock, they are generally dyed in hank dyeing machines. The hanks (or skeins) are suspended in the machines from rods or sticks mounted on frames. Yarns and slivers can be dyed in circulating liquor machines, in the form of wound packages.

Fabrics may be dyed using a range of machines. Wool can be also dyed in the garment form.

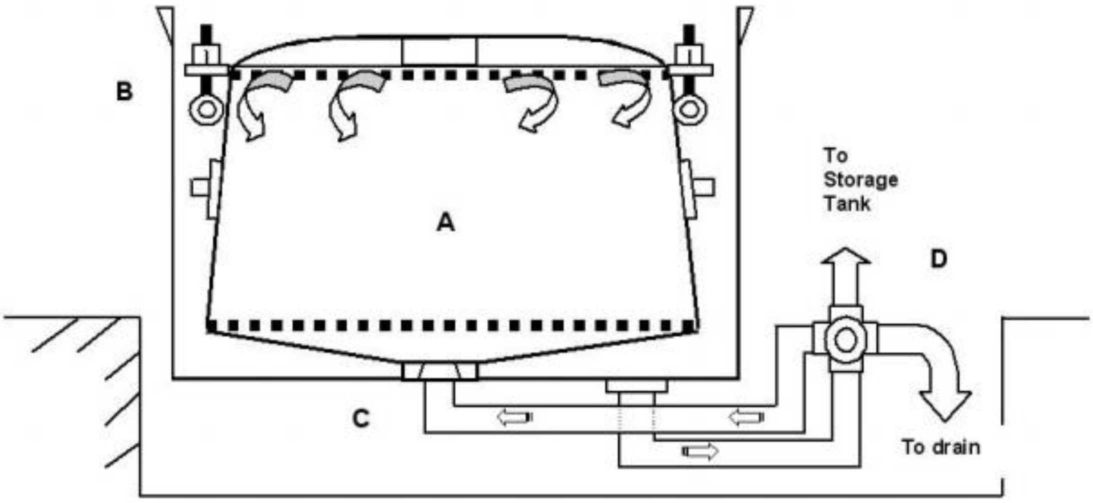
9.3. Loose Stock Dyeing

Wool is often dyed in fibre form. This of course means that the dyeing is done at the earliest stage of processing. Loose stock dyeing is most often used these days as a pre-colouration method in the production of woollen spun yarns in the carpet manufacturing industry where large lots of up to 12 tonnes per colour are produced.

9.3.1. Batch dyeing Machines

Various types of machine are used for dyeing wool in loose stock form. These include conical pan and pear-shaped machines (both supplied by Longclose) and radial flow machines, supplied by most of the major dyeing machinery manufacturers.

Photo: Loose stock dyeing machine



A: Fibre carrier with removable perforated lid and bade
B: Outer vessel
C: Spigot for carrier to liquor circulation system
D: Reversible pump and valve

***Figure: Conical Pan loose stock dyeing* Machine**

In the first two types of machine, the liquor is pumped through the pack of wool, which is packed relatively loosely in the container. In the conical pan machine it usually flows from bottom to top of the pan, overflowing and returning to the pump to be re-circulated, while in the pear-shaped machine the flow is usually from top to bottom. In both types it is possible to reverse the flow.

Because of the relatively loose packing of the wool in these two machines, relatively low flow pressures are required to give adequate penetration of the dye liquor through the pack. This gentle action causes minimum damage to the wool fibre, but productivity is rather low. In attempt to increase productivity, conical pan machines are nowadays frequently stamper-loaded, with the related problem of fibre damage during dyeing.

Figure given below shows a typical loose fibre dyeing machine. This machine can also be used for yarn packages, and for top sliver, but different frames or carriers are used for holding these. Loose stock forms a compact block of fibres through which the liquor is forced.

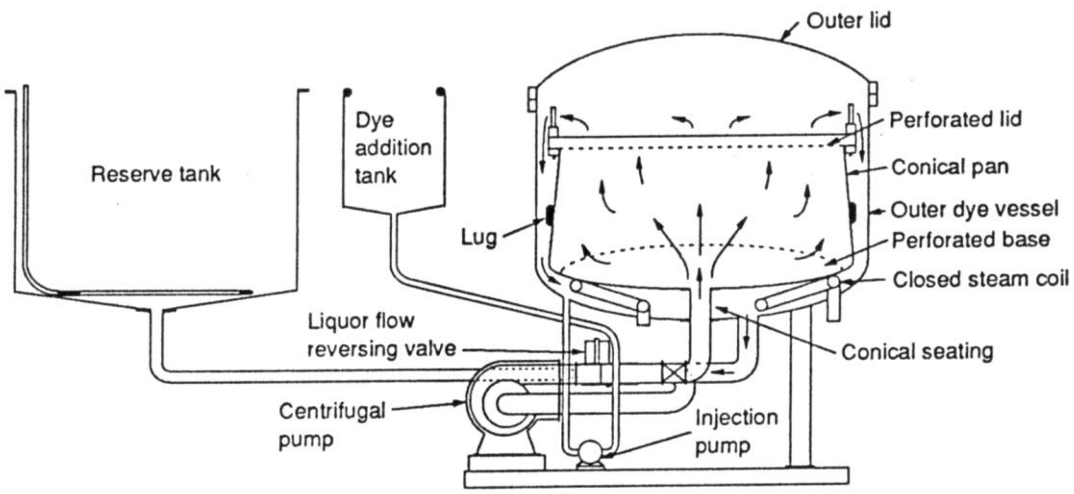


Figure: Loose fibre dyeing machine

9.3.2. Continuous dyeing of loose stock

A lap of loose stock is passed through a horizontal padding mangle, the dye liquor being contained within the radii of the pad bowls. The padded fibre is then passed into a dye fixation unit by a hydraulic ram to ensure continuous processing under pressure, and r.f. energy is applied. In the time taken for the fibre to pass through the r.f. field (approximately 15 minutes) it is evenly heated to the required temperature, and a further 10-15 minutes in the fully insulated dwelling zone effects full fixation of the dyes. Continuous backwashing and r.f. drying of the dyed loose stock completes the process; the dyed, dried wool emerges at a controlled moisture content of ±1 %.

9.3.3. Advantages of loose stock dyeing

(a) It is possible to dye very large lots of up to 12–14 tonnes per colour. This is done by dyeing numerous batches of perhaps 500 kilograms each and then blending all of these batches together.

(b) This method is ideal for instance when supplying carpet to large commercial installations such as hotels where many thousands of metres of the same colour may be required.

(c) This dyeing method provides the ability to even out any colour irregularities within the individual dye batches during subsequent blending.

(d) It provides a simple way of dyeing blends of different fibres as the optimum dyeing procedure may be employed for each of the individual fibres.

(e) By this method it is possible to mix different colours together to produce heather mixtures.

9.3.4. Disadvantages of loose stock dyeing

(a) Economy of scale is lost if small lots are dyed.

(b) Very long lead times are required between time of dyeing and production of finished product.

For dyeing of wool fibres High Temperature High Pressure Machine is used. Initially scoured fibres are loaded into perforated carrier having a central perforated projecting pipe. This carrier containing fibres is placed into another big vessel.

9.3.5. Wool fibres Step by Step Dyeing process

Photo: Perforated carrier with wool fibres loaded

Separate addition tank is provided for adding colour and chemicals required for dyeing. The stirrer is provided for proper mixing of additives.

Photo: Colour and Chemical addition tank

Colour solution is prepared in a separate plastic carboy. Initially required amount of dye powder is weighed (calculated as per percentage shade). Dye powder is pasted with little amount of water and then warm water is poured with stirring to dissolve the dye completely. This dye solution is then added into addition tank provided with dyeing machine.

Photo: Preparation of dye solution

In colour and chemical kitchen, different types of dyes, textile auxiliaries and chemicals are stored in a proper place. The main function of colour kitchen is issue the required quantity dyes and chemicals as per issue slip.

Photo: Colour and chemical kitchen

After loading the fibre into carrier, the lid is closed and the same is placed into main vessel.

Photo: Dyeing carrier loaded into main vessel

Photo: Fitting of Lid to the dyeing carrier

Photo: Dyeing carries and main dyeing vessel

Once the carrier is placed and fitted properly into the main vessel, the lid of main vessel is closed securely. Normally two types of dyes are used for wool dyeing, namely Acid dyes and Reactive dyes. The treatment is carried out by circulating the scouring or dye liquor through the fibre package.

Photo: HTHP dyeing machine ready for dyeing

Acid- metal complex dyeing is carried out in the as below.

(a) Scouring with soap at about 60^{o}C for 20 min.

(b) Washing with water

(c) Dye bath is prepared by adding the following additives.

Metal complex dyes	x %
Acetic acid	to adjust pH of 4.5

Ammonium Sulphate (Acid liberating/buffering agent)
Leveling agent

(d) Temperature is slowly raised to 100^oC

(e) Circulation is carried out at 100^oC for

Light shades	= 30 min.
Medium shades	= 45 min.
Dark shades	= 60 min.

(f) Cooling of machine to about 50^oC

(g) Drain off

(h) Soaping with non-ionic soap at 70^oC for 30 min.

(i) Washing

(j) Treatment with Antistatic agent at Room temperature for 15 min.

(k) Drain off

(l) Hydro- extraction

(m) Radio Frequency (RF) Drying

Reactive dyeing of wool

(a) Scouring with soap at about 60^oC for 20 min.

(b) Washing with water

(c) Dye bath is prepared by adding the following additives.

Acetic acid	to adjust pH of 4.5
Glauber's salt	3-5 g/l
Leveling agent	0.2 – 0.3 g/l

Above liquor is circulated through wool tops at room temperature for about 10 min. and then reactive dye solution is added and circulation is continued.

(d) Temperature is slowly raised to 85^oC

(e) The dye liquor is circulated through wool tops at 85^oC for

Light shades	= 15-30 min.
Medium shades	= 30- 45 min.
Dark shades	= 60- 90 min.

(a) Cooling of machine to about 50^oC

(b) Drain off

(c) Soaping with non-ionic soap at 70^oC for 30 min.

(d) Washing

(e) Treatment with Antistatic agent at Room temperature for 15 min.

(f) Drain off

(g) Hydro- extraction

(h) Radio Frequency (RF) Drying

Photo: Dyed wool fibres

9.4. Sliver dyeing

Sliver and top can be dyed in loose stock or similar machines. Below figure shows a typical dyeing sequence.

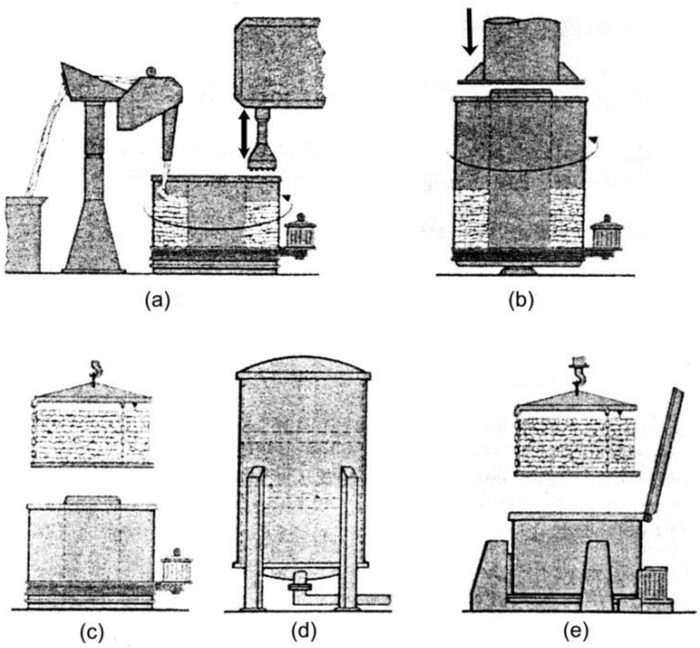


Figure: Sliver loading and dyeing sequence

a) Sliver is laid into a rotating carrier by a sliver coiler, with simultaneous wetting and stamping to compress the cheese.

b) Wetting and stamping during carrier loading can damage wool fibres. Wool sliver should be compressed by a hydraulic press after loading into a different kind of carrier.

c) Cheese removed from the press shown in (a). the cheese is supported by a perforated base.

d) Three cheeses, each on an individual base plate are dyed in a high temperature vessel.

e) A cheese is loaded into a hydro-extractor after dyeing, to remove excess water by centrifugal action before drying.

9.5. Package Dyeing

Package dyeing has been a subject of intensive development so package dyeing machinery is now very sophisticated and offers a number of advantages over hank dyeing, e.g.,

- Reduced yarn handling
- High and uniform rates of liquor circulation, leading to more level application of dyes than is possible with hank dyeing
- Amenable to automatic control, leading to reproducible dyeings
- Low goods-to-liquor ratios, giving savings in water, effluent and energy
- Totally enclosed machinery, giving good working conditions in the dyehouse
- High temperature dyeing possible
- Large batches.

9.5.1. Sliver and top package dyeing

Sliver and top is often dyed in bump form. Bump tops are made as follows as shown in figure.

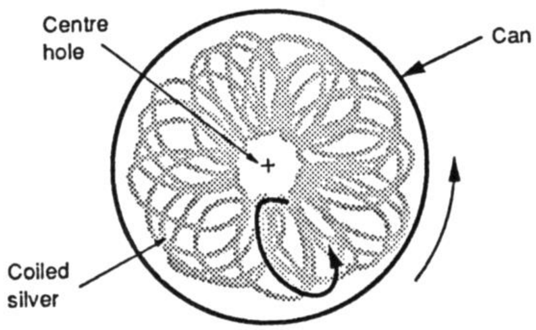


Figure: Coiling of sliver into a can to form a bump top

i. Sliver coiled into rotating can;
ii. Transfer full can to hydraulic ram
iii. Compress sliver, and
iv. Tie coiled sliver to keep it compressed

Alternatively, the can is lined with a plastic bag and the compression ram is fitted with a suction device to draw air from the bag. Once compressed, the bagged sliver is tied and the bump top stored until needed for dyeing.

The Top dyeing machine is shown in figure below.

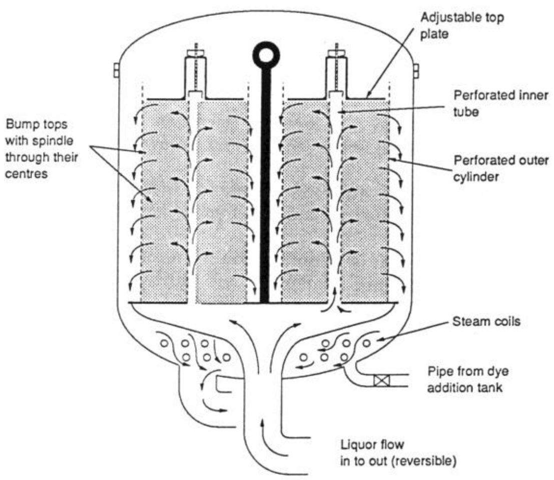


Figure: Bump sliver dyeing machine

It operates on the same principle as a loose stock dyeing machine, with the main difference being the means of supporting the goods during dyeing. The goods remain still while the liquor is moved by a pump. Most top dyeing machines are high temperature, pressurised machines which operate at relatively low liquor ratios of about 5:1.

Wool will be dyed in top form rather than in yarn form for the following reasons:

- Several dye batches can be blended into a big batch of the same shade during finisher gilling.
- Batches of different colours can be blended to make mixed colour yarns.
- Shades that are difficult to dye evenly on yarn can be dyed on top sliver; subsequent gilling will blend out any unevenness.
- A stock of slivers of different shades can be stored, from which a variety of worsted yarns and fancy yarns can be made.

Note that worsted yarn is very rarely made from loose-stock dyed fibres. In the worsted process dyeing is usually left until after combing, to ensure that the fibres have undergone the most severe mechanical processes before the weakening effect of dyeing occurs. In woollen processing, where the retention of good fibre length and strength is less critical to spinning efficiency and yarn quality, loose stock dyeing is common.

9.6. Top Dyeing

Wool is often dyed in top form. Wool tops are produced after combing, which is a preparatory stage before worsted spinning. The tops are actually balls of sliver that weigh anywhere between three and 10 kilograms, or are more commonly made into bump tops of up to 20 kilograms. Modern top dyeing machines are multipurpose machines, which may be used for dyeing yarn on packages and also loose fibre**.** They are able to dye at high temperatures under pressure so may be used for dyeing fibres other than wool.

Wool tops are generally dyed in radial flow machines, the same machines are used for loose stock dyeing but with a different material carrier. Different machines are available, e.g. Longclose top dyeing machine, Obem top dyeing machine, vigoreux printing machine

9.6.1. Longclose (UK) large bump tops

Longclose (UK) is one of the companies who have developed a system for handling the large bump tops. These are made by coiling 20-22 kg top sliver into a can between a central mandrel and the can wall, on top of a woven plastic fibre disc placed on the false bottom of the can. A second woven disc is put on top of the coiled sliver, and the mass of sliver compressed in a bumping press. The bump top is then secured by strings tied around the top. Four of these tops are compressed into a dyeing cage consisting of an outer removable perforated cage and a removable perforated spindle. Four cans can be located on a material carrier and locked into place, thus allowing 320 kg wool to be dyed in one batch.

For unloading after dyeing, the individual cages are lifted by crane on to a transporting bogie, and the outer perforated cage is unlocked from the base and lifted away by the crane. The central perforated spindle is then unlocked from the internal seating on the material carrier base and lifted vertically from the column of dyed tops, again by means of the crane.

Figure: Longclose large bump top dyeing – Unloading after dyeing

9.6.2. Dyeing process of Wool Top Step by Step

Photo: Wool top preparation (A)

Photo: Wool top

Photo: Addition tank, dyeing vessel and top carriers

Photo: Wool top carriers

Photo: Outer vessel of Wool top dyeing machine

Photo: Dyed wool tops

Wool top dyeing steps:

- Tops are prepared after wool fibre combing
- Tops are loaded into carriers of top dyeing machine
- Scouring is carried out detergent (soap)
- Tops are washed with water thoroughly
- Acid or reactive dyeing is carried out (process mentioned as earlier)
- Soaping is carried out at boiling temperature
- Finally tops are washed with water

9.6.4. Drying of Wool Tops

After dyeing, wool tops can be dried with hot air drying or Radio-frequency drying. In hot air drying, the top sliver is passed down a backwasher coupled to a hot air dryer, usually this is a drum dryer, but brattice dryer are also used. Radio-frequency (r.f.) drying for wool is now an established industrial technology, with an increasing number of companies now offering conveyor belt r.f. drying.

9.6.5. Advantages of top dyeing

Top dyeing shares similar advantages to loose stock dyeing and is the first opportunity to dye the fibre in the worsted spinning production chain.

9.6.6. Disadvantages of top dyeing

As with loose stock dyeing, the economies of scale are lost if small lots are required. Once wool tops have been dyed, they then need to be recombined prior to spinning, which adds an additional cost.

9.7. Yarn Dyeing

Dyeing is often carried out in yarn form for a number of reasons. For colour woven fabrics such as checks and fancy designs, and also for multicoloured knitted garments, the requirements for some individual colours may be very small and there may be a large number of colours in the design. In this situation it is not practical or cost-effective to dye large lots of tops for each colour. Yarn can be dyed in lots of from one kilogram to 500 kilograms or 1000 kilograms, depending on the size of the machines available.

Hanks for carpet, hand knitting and machine knitting is still predominately dyed in hank form, although there are developments taking place which will allow these yarns to be package-dyed.

9.7.1. Yarn Package Dyeing

Package dyeing provides the textile industry wirh an opporruniry to colour yarn at the larest possible stage prior to fabric manufacrure. This is of prime imporrance if the dyer is to respond rapidly to changes in fashion and consumer demands. Package dyeing is advantageous for the finer counts of yarn which are less amenable to handling in large hanks.

In order ro meet these demands technical innovations have been, and are being, adopted by the wool textile industry to ensure that package dyeing meets not only the technical but the aesthetic requiremenrs of the indusrry.

9.7.1.1. Package preparation

Package dyeing is generally only as good as the package preparation. Development of package centres has made it possible to improve level dyeing performance, to increase the size of the load and to reduce fibre damage. For many years perforated plastic cones have been widely used as support centres for package dyeing, but several disadvantages are associared with their use:

- ✓ payloads in a given machine are limited
- ✓ spacing devices are required between the cones,ma king loading and unloading operations labour-intensive
- ✓ non-un iform column densiry requires high flow rares to achieve level dyeing
- ✓ cone slippage can occur.

A recent development to overcome these disadvantages is the use of biconical package cenrres.The internal geometry of these centres allows packages to be prepared on conventional random winding or spinning machinery. Grooves in the base of the formers correspond with spines on the top, so that interlocking and hence press-packing can be achieved to form a parallel-sided dyepack (PSDP).

A wide variety of centres is available to suit different winding machines, traverses and spindle diameters; completely parallel centres are also now available (Figure).

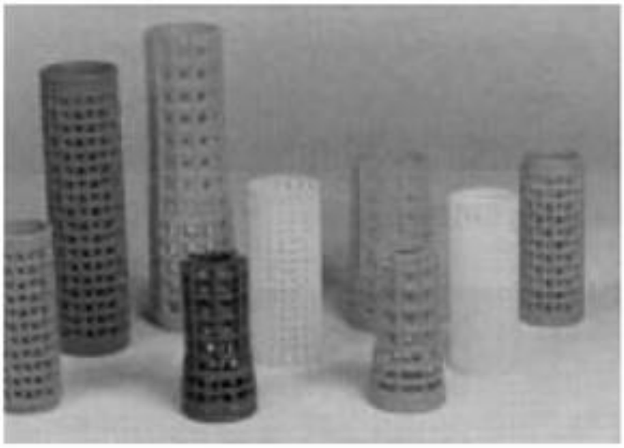


Figure: Range of package centres

Press-packing is generally carried out to between 15 and 22% to produce a uniform parallel-sided column. Package density is usually in the order of 350 g l^{-1} prior to press-packing, and may increase to 450 g l^{-1} after pressing. A major advanrage of using the press-pack/PSDP method is that payloads in a given machine can be significantly increased and large packages can be dyed wirh complete levelness: packages of up to 3.5 kg weight and 300 mm diameter are being successfully dyed on worsted weaving yarns. Another advantage is that loading and unloading operations are significantly reduced, as the entire column can be unloaded and spacers are not required .

A major European dyehouse has found since the introducrion of the parallel-sided system using the BIKO dyepack (Figure below) flow rates can be effectively reduced from 30 to 12-15 l (kg min)$^{-1}$. This reduction in flow rate has been achieved with large BIKO dyepacks (up to 3.5 kg) wirhout reduction in level dyeing performance. There is every indication that mechanical damage is reduced at the lower flow rare, with additional benefits in terms of a reduction in the amount of electrical energy consumed for running the pump and reduced wear and tear on the motor.

Biconical package centres such as BIKO or Zimmermann unwind perfecrly to the end of the cone; with the use of dyebath lubricants, waste is virtually eliminated thus reducing costs. They are thus ideal for use in direct warping, weaving and possibly even knitting. Moreover, modern high-speed weaving machines, including air jet weaving machines operating with very high weft insertion rates, can be fed directly by BIKO-style dyepacks without the need for rewinding.

Zimmermann have produced parallel centres and also a package centre that contracts during dyeing and hence allows for yarn shrinkage. The Engel Multiflex package centre may be axially compressed up to 50% of its original length,and during dyeing the tube can shrink up to 13% in diameter. Both changes occur without distortion of the form of the package and the tension in the inner layers of yarn next to the centre is minimised. The variety of package centres available enables a wider range of yarn types to be package-dyed than was previously deemed possible.

Figure: Dyehouse using BIKO dyepacks

9.7.1.2. Machinery

Three basic types of machinery are currently being used for package-dyeing wool yarns: horizonral- and vertical-spindle dyeing machines and tube-type machines.

9.7.1.2.1. Horizontal-spindle machines

These are of two types. The first is the rectangular machine primarily designed for hank dyeing, but modified to accommodate package frames, with increased capacity pumps to give the higher flow rate required for packages.

The other type is a horizontal autoclave into which is wheeled the carrier containing the horizontal spindles; one example is the Thies Eco-bloc machine (shown in Figure below).

Figure: Thies Eco-bloc horizontal-spindle machine

The advantage of this type of machine is that less headroom is required, no overhead cranes or pits being necessary. On the other hand, the payload is lower than for vertical-spindle machines, and limited press-packing and sagging of the packages may occur, leading to unleveI dyeing.

9.7.1.2.2. Vertical-spindle machines

These are the most commonl y available and widely used machines for package-dyeing. Press-packing is possible, with the resultant advantage of higher payloads and minimum liquor-to-goods ratio, with subsequent savings in resources and energy. It is necessary with these machines to have either a pit or a working platform, and overhead hoists are required for loading and unloading. The machines illustrated in (Figure: Dyehouse using BIKO dyepacks)

Most of the machines available are of similar basic design, though there are differences in pumping systems and ancillary features.

Figure below shows a typical yarn package dyeing machine.

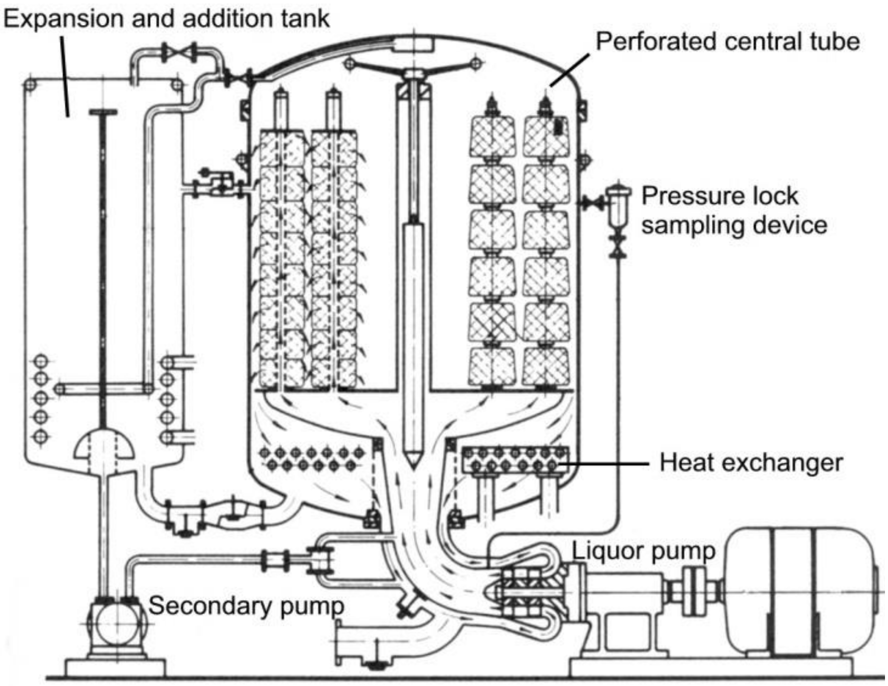


Figure: Yarn package dyeing machine

For package dyeing, the yarn is wound on to a package centre. These cones or centres are perforated so that the liquor is able to flow from inside to outside, or from outside to inside of the package. The packages are loaded on to spindles. Spindles are perforated pipes closed at the top end, and attached to a base plate that allows the liquor to flow through the spindles and packages.

In package dyeing there is no movement of the yarn during dyeing, so very fine yarns, high twist yarns and singles yarns can be dyed without damage. The yarn must be dyed perfectly level as there is no blending after dyeing as with loose stock and top dyeing. To achieve level dyeing of yarn packages:

- The packages must be of a consistent size and density, as can be achieved by using modern precision winding machines;
- The dye liquor must be free of particulate matter that could filter out in the yarn;

- Rapid strike of dye must be avoided;
- The flow times of out-to-in and in-to-out must be correct;
- Foam should be suppressed because it severely reduces the liquor flow and may result in undyed spots in the yarn.

Despite these stringent requirements, yarn dyeing is popular because it allows colouration to be done at the last stage before weaving or knitting. Thus it enables a quick response from the spinner to orders received from manufacturers. Because the yarn is constrained in package dyeing, the dyed yarn tends to be less bulky (ie, lean) than the same yarn which had been hank dyed

9.7.1.2.3. Tube-type machines

There are two kinds of tube machine. Both types work at a low liquor-to-goods ratio of 4:1, enabling reductions in energy, water, effluent and chemicals to be made, but the horizontal type offers advantages over the vertical tube described earlier.

Ease of installation and maintenance: The machines are installed at floor level without the need for pits, platforms or overhead cranes.

High level of reproducibility/continuity: Because of the lower volume of dye liquor, the frequency of the dye l iquor circula tion cycles through the yarn packages is increased, and this ensures greater reproducibility as increased exhaustion is consistently achieved .

High level of load flexibility: Multiple-tube machines are capable of having tubes blocked off.

Ease of use: As the machine is at floor level, loading operarions are carried out on a horizontal basis, and the simplicity of loading and unloading operarions allows down-time of the machines between batches to be significantly reduced.

Package dyeing is now a very widely used technique for producing coloured yarn for colour woven fabrics and knit goods. Modern package dyeing machines have a high degree of versatility with regard to batch sizes and the fibres which may be dyed.

The machines may be operated under pressurised conditions at temperatures up to 140°C making it possible to dye fibres such as polyester. The yarn to be dyed is wound onto perforated dye centres which may be disposable plastic or stainless steel springs, which are reused. The packages may be in the form of cones, cheeses, muffs or bobbins.

The packages are loaded onto a carrier with perforated spindles and are normally compressed by about 30% to reduce the possibility of channelling and leakage between packages. These machines have very efficient pumping systems with the facility to reverse the flow direction and can dye at liquor ratios down to 1:6. A general rule of thumb for flow rates is that 30 litres per kilogram of yarn per minute is about optimum.

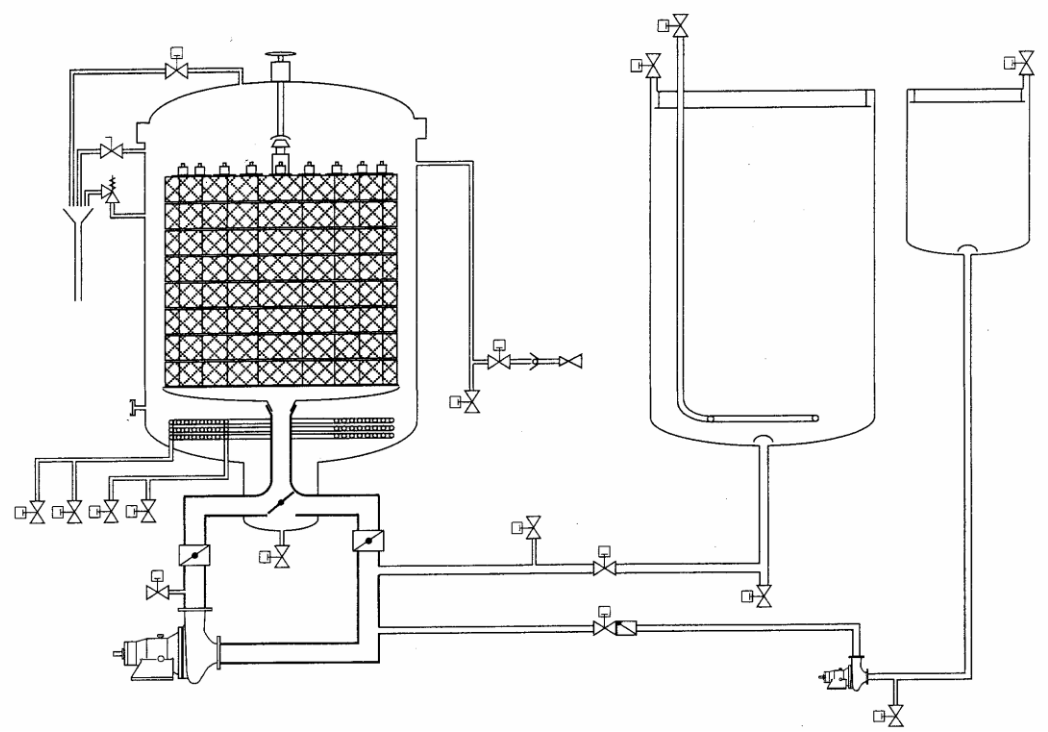


Figure: Schematic of pressure package dyeing machine.

9.7.1.3. Advantages of package dyeing

(a) Reduced lead times from order to finished product – reduced stock holding.

(b) Extremely versatile in batch sizes – any size lot from one kilogram to 1000 kilograms, depending on machinery available.

(c) Yarn packages may be assembled on two-for-one twisters thereby saving a winding operation.

(d) Improved spinning yields as fibre is not damaged prior to spinning.

9.7.1.4. Disadvantages of package dyeing

(a) Loss of yarn bulk if special dyeing methods are not used.

(b) Yarn flattening on inside of package.

10.7.2. Hank dyeing

The tradition method of dyeing yarn is to do it in hank form. It is carried out in machines with fairly gentle liquor flow so as to reduce channelling. The hanks of yarn are supported by sticks (steel rods) at the top and bottom of the machine to cater for reversal of the liquor flow direction.

A typical hank dyeing machine, the single-stick type, is illustrated in Figure below. This is most commonly used despite the technical advantages of double-stick machines. Machines of this type can be made in a variety of sizes up to 1000 kg capacity, whereas there is an upper limit to the size of the other types.

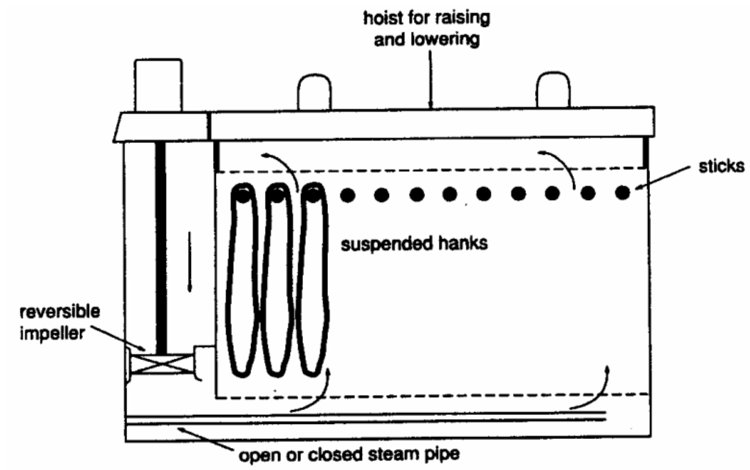


Figure: Hank dyeing machine.

The hanks of yarn (e.g., "jumbo" hanks of 3.5-5 kg when heavy counts of carpet yarn are to be dyed) are suspended from stainless-steel sticks mounted on a shallow frame constituting the lid of the machine. The body of the machine comprises a rectangular vat with a perforated bottom and an impeller at one end. Two impellers are provided on the largest (1000 kg) machines; and intermediate impellers under the false bottom may be added to improve the uniformity of circulation over the length of the machine. Heating is by a steam coil (closed or open) located under the false bottom.

Dyeing is carried out at goods-to-liquor ratios around 1:20. The yarn is placed in the dye vessel using an overhead crane, with the liquor flowing downwards towards the false bottom in order to help straighten the load while it is being wet out and to keep the packing uniform. During the dyeing cycle, the flow is usually upwards through the pack, lifting the hanks off the sticks, thus ensuring all parts of a hank have access to the dye liquor, and packing them together to preclude channelling.

The temperature cycle in a hank dyeing machine is preferably controlled by a microprocessor. Dyeing is usually carried out at 98^oC to avoid boiling the liquor, which brings the associated risk of cavitation at the impeller and a consequent loss of circulation.

9.7.2.1. Advantages of hank dyeing

(a) Low liquor flow rates and very little tension on the yarn provide a very gentle action during the dyeing cycle and maintain the yarn bulk or loftiness.

(b) Improved spinning yields.

(c) Reduced lead times and inventories.

(d) Ideal dyeing system for wool and acrylic yarn which is easily deformed during dyeing.

10.7.2.2. Disadvantages of hank dyeing

(a) Little flexibility in batch sizes as machines must be fully loaded

(b) Hank formation and back winding operations add extra cost.

(c) Loading material carriers is slow and labour intensive.

9.8. Fabric/Piece Dyeing

Dyeing in fabric form minimises the time between shade selection and retailing for woven goods. However, it is limited to the production of plain shades.

Uniformity of shade is critical in piece dyeing and it is therefore essential to use dyes that are capable of producing a level dyeing result. These dyes generally do not have good fastness to washing or wet processes but this is not a serious problem, because most of the products that are manufactured from piece dyed material will require fastness to dry cleaning only.

Unlike yarn and fibre, fabric is dyed in machines in which the material is circulated through the liquor as a continuous loop. Fabrics may be dyed either in rope form or in open width.

Fabric is dyed using a number of different types of machines including winches, beam dyeing machines, jigs and jet dyeing machines. For wool fabrics which are produced from woollen spun yarns, winches are often preferred as they can have a positive effect on fabric consolidation. However, for wool and wool blend fabrics produced on the worsted system, soft action jet dyeing machines are usually preferred. In special cases with wool fabric, which is very delicate or prone to creasing, it is sometimes necessary to dye them on a beam dyeing machine.

Traditionally wool pieces, both worsted and woollen spun have been dyed in winches. A move from the traditional deep-draft wool winches to the shallow-draft machines has improved the dyeing efficiency of winches, due to factors such as the following:

- ✓ closed-coil steam heating under a false bottom, giving even temperature distribution throughout the winch
- ✓ lowering of the winch reel and driven jockey roller, thus reducing the drag on pieces being lifted out of the dye liquor
- ✓ variable machine speed, so that optimum speed for different fabrics can be selected
- ✓ aids to liquor circulation (pump or impeller)
- ✓ even distribution of dyes and auxiliaries across the width of the winch, giving reproducibility of shade from piece to piece within one dye lot.

9.8.1. Rope dyeing methods

Wool fabric is dyed in two forms, rope form and open width form. The fabric in rope form is dyed on winch and jet/soft flow dyeing machines.

9.8.1.1. Winch dyeing

Figure below shows the main features of a typical winch, one of the oldest dyeing machines. Pieces of fabric, sewn together at the ends to form very long loops, are dyed side by side. In an average-sized winch machine, about six pieces of wool fabric are dyed together. The fabric is moved through the liquor by the driven winch (also called a reel).

The winch speed varies to suit the fabric within a range of 30 to 80 metres per minute. Wool fabrics are dyed at low speeds to prevent felting. If cloth edges tend to curl up, or if the fabric surface is easily abraded, the pieces are bagged. That is, the selvedges are brought together and sewn to form a tube of cloth with the fabric face on the inside. Dyes and chemicals are added to the front compartment to pass slowly through the perforated partition so that they don't come into contact with the fabric in a concentrated form.

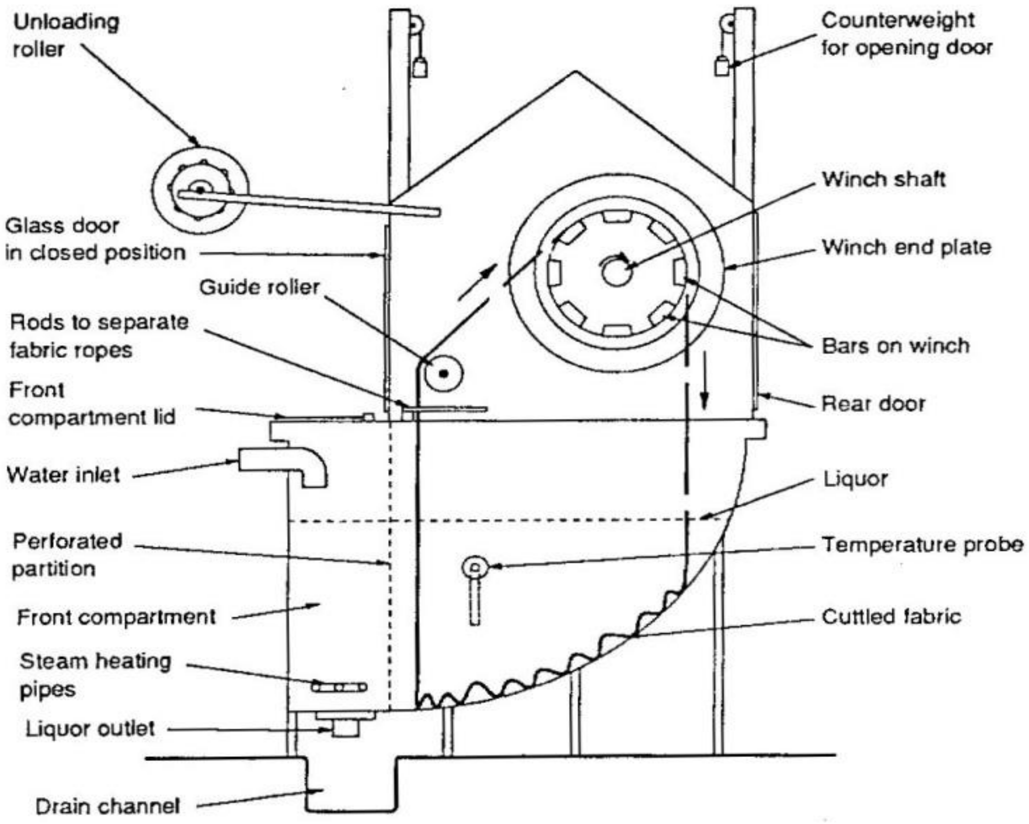


Figure: Winch dyeing machine

The drawbacks of winches, which led to the development of jet dyeing machines, are:

- High liquor ratio, which makes heating slow and expensive, and wasteful of chemicals;
- Long dyeing cycle because the dye/liquor interchange (goods move, liquor still) is poor, thus requiring gradual dyeing to get level results.
- Creasing, rubbing, and chafing can occur, especially if the fabric ropes entangle and slip against the winch bars. Thermoplastic fibres can have creases set in by the hot liquor if the folds in the fabric are not rearranged often enough during dyeing.

- Temperature variations can occur across the width of the machine. For example, it can be cooler at the sides, causing the outside pieces to dye lighter. This problem is overcome in winches fitted with a dye circulation pump and piping.

9.8.1.2. Jet and Overflow dyeing

Since 1971, there has been a rapid development in the field of jet and overflow machines. These were originally described as high-temperature piece-dyeing machines for textured polyester, to overcome the problems with carrier dyeing in atmospheric winches. The jet dyeing principle was later extended to the dyeing of cotton knitted goods and polyester blends with cotton or wool.

In jet dyeing machines, both the goods and the dye liquor are moved. The cloth in rope form is lifted out of the dye liquor by a small reel and, together with the circulating dye liquor, is drawn thorough the jet or venturi and passes to the back of the machine. A venture (or nozzle) is a pipe that narrows and then widens out again. Dye liquor is pumped through the venture, and it flows faster through the narrow part, causing suction that moves the cloth forward.

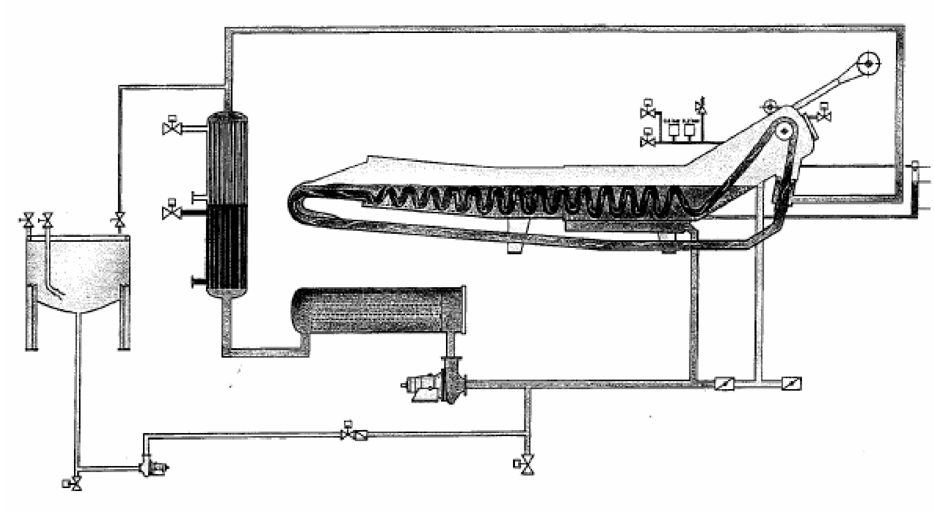


Figure: Jet dyeing machine

The speed at which the cloth moves around the machine is varied by adjusting the amount of liquor flow to the venture, and may be as high as 400 metres per minute. It was logical that jet dyeing machines should be considered for the dyeing of wool fabrics since replacements were needed for the old winches, and also a machine was required which would overcome the problems of winch dyeing, particularly the formation of running marks. There are about five basic machine types.

Group 1: Fully and partially flooded jet dyeing machines with hydraulic fabric transport via a venturi nozzle.

Group 2: Overflow machines with driven winch reel, a combination of hydraulic transport and driven winch . These are usually partially flooded machines and are considered to be of gentle action.

Group 3: Machines with a driven winch reel and a jet nozzle.

Group 4: Combined overflow/jet nozzle machines with a driven winch.

Then have recently modified the Then flow machine, specifically with wool fabrics in mind. The jet has been replaced with a specially designed overflow system, which guarantees an intensive liquor flow action on the fabric rope with the additional feature of optimum fabric displacement by means of generated impulses. The elongated storage section of the machine is almost fully flooded, so that the fabric rope is floated forwards through the liquor in a relaxed state towards the take-up point. This ensures a gentle fabric transport, rendering the machine specially suitable for dyeing goods with a delicate surface and a tendency to crease, such as woollen cloth.

The most innovative development in piece dyeing is the Then Airflow, introduced by Rudolph Then at the Paris ITMA 1987 exhibition.

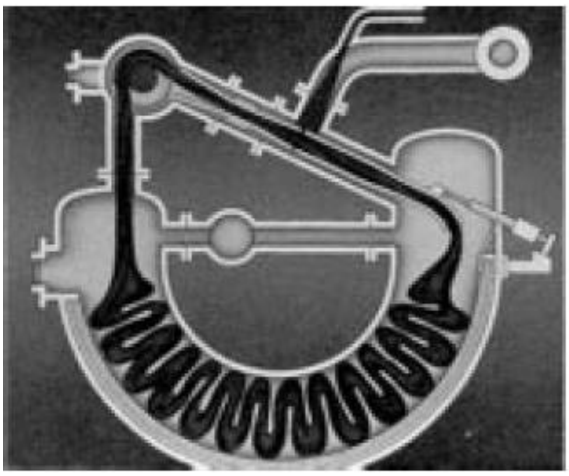


Figure: Then Airflow Piece-Dyeing Machine

This uses a gas stream - either humid air or an air/steam mixture - to transport the fabrics through the machine, which significantly reduces the quantity of liquor required to dye the Material to liquor ration of 1-2:1 are quoted. The dyeing liquoris added to the gas stream by means of an injection pump. Although this machine has not yet been proven to be satisfactory for piece dyeing wool fabrics, initial trials are promising.

9.8.2. Open Width Dyeing Methods

Some fabrics are dyed open width, either to prevent rope creasing or because the fabric does not process well in rope form. There are two kinds of dyeing machines for exhaust dyeing of fabric in open-width form: jig dyeing machines and beam dyeing machines.

9.8.2.1. Jig dyeing machines

Jigs are commonly used to dye woven fabrics of cotton, viscose rayon, and silk. These fabrics are not damaged by the backwards and forwards action, and their absorbency allows them to pick up dye liquor during the short immersion time. As Figure 14.12 shows, jigs achieve goods/liquor interchange by moving the fabric back and forth through stationary dye liquor, as occurs in winches. However, in jigs the fabric is out of the dye bath for most of the time. A pump circulates the dye liquor to keep its temperature uniform, and to ensure thorough dye mixing.

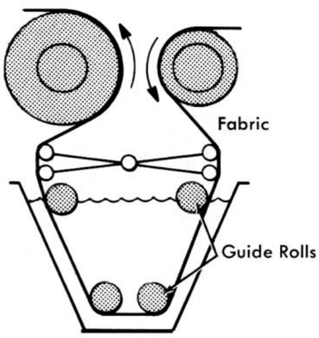


Figure: Atmospheric jig dyeing machine

A number of fabric rolls are joined together while being wound on to a driven roller (detachable drive) mounted on a batching frame. The fabric is drawn off the batching frame on to one of the two main rollers in the jig dyeing machine.

During dyeing, the fabric is wound from the full main roller to the other roller, and then back again, for a set number of passages through the dye liquor. Each passage is called an end. Dye is usually added in stages over several ends to prevent tailing, where one end of the batch is dyed darker than the other end.

The greater the length of fabric being dyed, the faster the cloth speed needed to achieve a given end time. Small batch machines have a cloth speed of 10 to 60 in/min, and for larger machines, 20 to 120 m/min. Although the fabric is not immersed in the dye liquor for long in jig dyeing, the fabric is saturated with dye liquor on the rolls, and so dyeing takes place. Excess water is removed after dyeing by squeezing between rollers or by drainage while the whole batch is kept slowly rotating on a batching frame

9.8.2.2. Beam dyeing

Both woollen and worsted fabrics can be piece-dyed on beam dyeing machines. The beam dyeing process is a form of package dyeing in which the fabric is dyed in open width on a perforated cylinder. Atmospheric and high- temperature machines are available, the direction of the liquor flow can be reversed and a high degree of automation can be achieved. The preparation of the beam of fabric must be carried out with care, since any creases formed during winding or shrinkage on the beam become permanent when processed at the boil, but this is avoided by proper preparation. Dyes must be carefully selected, since particles of precipitated water-soluble dyes can be filtered our during dyeing.

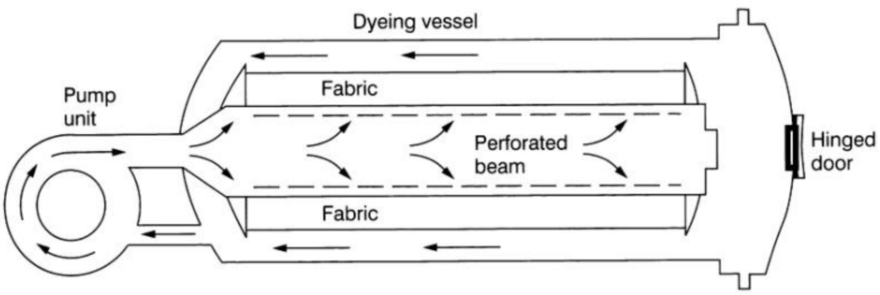


Figure: Beam dyeing machine

Beams are especially suitable for dyeing fabrics that must be finished open width but cannot be dyed in jigs because, for example, the fabric is not dimensionally stable enough for repeated winding, or is so fine, and hence of such length, that ends in jig dyeing would take too long.

Figure: Beam dyeing machine

Figure: Beam batching machine

Beam dyeing machines are ideal for dyeing warp knit fabrics, and worsted woven fabrics that have a flat surface and firm handle, and so are not harmed by being tightly wound.

One of the limitations of beam dyeing is the amount of fabric which can be dyed in a single lot. This is dependent upon the air porosity of the fabric: the more highly set the fabric is, the lower its air porosity and the smaller the amount of fabric which can be dyed satisfactorily.

9.8.3. Drying piece goods

After dyeing and before finishing, the fabric is dried. In order to conserve energy it is essential to extract mechanically as much moisture as possible from the fabric.

The most efficient method is hydro-extraction in a centrifuge, where residual moisture content can be reduced to 25-30% depending upon fabric type. Other methods include passing the fabric over a suction slot or through a pad mangle; the last-named method is the least efficient, leaving a residual moisture content in the order of 50%.

After hydro-extraction the fabrics are usually dried on a hot air tenter. The wool fabric should be dried to a moisture regain of 10-14% (i.e. 10-14% of moisture left in the fabric). Modern tentering machines are fitted with automatic controllers to allow drying to a particular moisture regain.

9.8.4. Advantages of Fabric Dyeing

(a) Very short lead times and minimum stockholding of finished goods.

(b) Amounts exactly matching the size of the order may be dyed.

(c) Leads to highly efficient processing as only white fabric needs to be woven or knitted.

9.8.5. Disadvantages of Fabric Dyeing

(a) Restricted colouration flexibility as only solid colours can be dyed unless blends of different fibres are used

(b) A certain amount of permanent set may be imparted to the fabric which may prove undesirable in later finishing operations.

9.9.1. Carpet Piece Dyeing

There are five basic systems for piece dyeing carpets, and most are represented by a range of machines made by various manufacturers.

9.9.1.1. Pad-steam: This system is based on the application of thickened dye liquor to the carpet at open width, not necessarily by padding but more usually by special applicator. This is followed by steaming (generally at 100-103°C) in saturated steam for 4-8 minutes and finally the removal of auxiliaries and any unfixed dye by washing-off. All these machines are suitable for wool.

9.9.1.2. Pad-batch: This system is based on the application of dye liquor at room temperature to the carpet in open width. The carpet is then rolled, sealed with polythene and rotated at four turns per minute for 12-48 hours, depending upon the depth of shade required. Any unfixed dye is removed by a mild afterwash in cold washer.

9.9.1.3. Continuous exhaustion: This system, the 'Fluid-0-Therm', is based on the exhaustion of dye in a long shallow bath, the dye liquor moving along the bath at the same rate as the carpet and being continuously replenished at the entry. The texture change is similar to that produced by pad-steam methods.

9.9.1.4. Winch/beck: Carpets are normally dyed at open width in winches, and even dyeing across the width of the fabric is achieved by having a pumped liquor circulation. Because the carpet is constantly moving through boiling dye liquor for long periods of time (up to twelve hours if several shading additions are necessary) this method does tend to change the texture of cur-pile wool products quire markedly. Only loop-pile textures and cur-pile carpets with well-set yarn tufted in very low and very dense constructions are considered suitable.

9.9.1.5. Foam dyeing and Fluidyeing: This system is based on the pad-steam principle, except that the carpet is not padded as such; instead, dye liquor is forced into the pile by means of a special applicator. Dye liquor is injected through a slot under whatever pressure is needed to penetrate the pile.

9.9. Garment Dyeing

Garment dyeing machines have long been used for dyeing socks, stockings and pantyhose and are sometimes used for dyeing fully fashioned knitted garments. There are a number of different types of machines from rotary drum machines to side and overhead paddles and the more modern front-loading rotary drum garment dyeing machines. The front-loading rotary drum machines have the advantage that they are also used for extracting water from the dyed goods.

Fully fashioned garments and body blanks for the cut-and-sew industry are increasingly dyed in garment form, as this allows the supplier to delay the choice of shade until the latest possible time before the garments appear on retail counters; thus only the shades which are in popular demand are dyed that is, fashion shades.

Most of the rotary-drum machines incorporate a centrifuging cycle. This means that the operator handles damp, rather than thoroughly soaked, garments at the end of the dyeing cycle, and also that dirty liquors are removed from the garments during the process (after scouring, for example) much more efficiently than in side-paddle machines. The number of rinsing cycles can therefore be reduced by 50%, with a consequent saving in water usage.

In new developed garment dyeing machine, large wheel is divided into 12 compartments. The compartment divisions are made from perforated stainless steel and are aligned non-radially: this also allows them to open more easily than does the conventional open or Y-shaped compartment. A liquor ratio of 6:1can be used for wool garments using a speed of 1rev./min, as there is a constant circulation of liquor by pump. Loading and unloading is easy, as on the loading side of the machine the floor of the compartment is level, and for unloading at the opposite side the floor is tilted to allow the garments to slide out into waiting carts.

Once the garments are dyed, the dyeing machine is tilted and unloaded on to the lower end of the conveyor belt. They then travel in the conveyor into the open door of the rumble-drying machine.

Chapter 10

AUTOMATION IN WOOL DYEING

Automation is now well established in the dyeing industry and robotics are being introduced at an ever-increasing rate. The Robotised, 'light-out' dye house operated with the minimum of staff is becoming more common. A 'light-out' operation is likely to be run by mechanical and electronics engineers and not dyers in the conventional sense. Automation consists of:

- Programmable process control of the dyeing machinery (by microprocessors)
- Automatic control of dissolving and dispensing of the dyes, pigments and chemicals in a central colour kitchen
- Computer controlled weighing of solid material, with automatic stock control and the printing of recipe and process cards
- Instrumental process control measurement, computerised colour matching
- Central computer (network), computerised management systems

10.1. Benefits of Dye House Automation

Programmable process control (by microprocessors) results in 10-30% saving in water and energy usage as well as 5-15% saving in dyes and chemicals.

Computer controlled weighing of solid material, with automatic stock control and the printing of recipe and process cards save about 10-15% dyes, pigments and chemicals.

Lower discharges with less pollution and lower cost of effluent treatment.

The cost of automation is relatively low, typical return on investment figures are in the range of three months to one year, not including the value of quality and reliability improvements.

10.2. Cost Saving with Automatic Dye Dispensing

Even if full automation is not being considered, a dispensary with its own dedicated staff greatly increases the efficiency and reproducibility of dyeing.

A separate dispensary is obligatory on health and safety grounds in many countries. The installation of a dye house control system and a dispensary allied to it will have a payback of about one to two years. The saving accrued include typically a 50% reduction in labour, a 30% increase in productivity, a 15 to 20% saving in dyes, chemicals and energy.

Totally automated dispensaries can prepare about 20 dye baths per hour and are thus only justified for a dye house equipped with many machines programmed with short dyeing cycles.

This level of automation would be difficult to justify for a all dye house with less than 10 machines.

Photo: OBEM automated loose stock and top dyeing

Photo: OBEM automated hank dyeing machine

This fully robotized OBEM automated hank dyeing machine use a specially designed spray hank arm, the hanks are processed without tension. The system is particularly suited for fine and soft yarns.

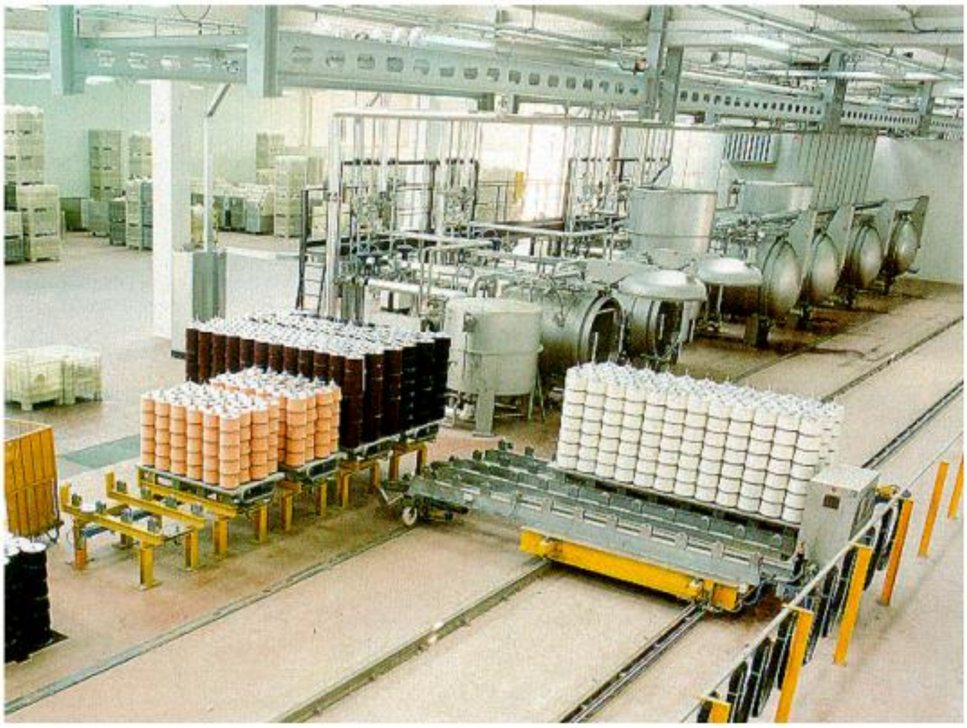


Photo: RBNO robot package dyeing plant

Photo: OBEM robot package dye house

Chapter 11

PROCESS CONTROL AND QUALITY CONTROL IN WOOL DYEING

11.1. Process Control

The concept of process control measures are becoming popular now days due to two main reasons i) Growing competitions and increasing cost of production. (ii) Textile industry now a day is facing a very stiff competition. This competition is at macro and micro level. Micro may be within a country and macro means competition from industry world over.

Under these circumstances, price and quality becomes important criteria, therefore, process control becomes more essential, for achieving overall success. Role of process control in wet processing is to achieve overall profit and higher efficiency. Certain tools are needed to control various phases of production. The most important function of process control lab is to reduce the cost, by ensuring the production with required quality, with the help of standard specification.

11.1.1. Approach to Process Control

The choice of process condition, for the given product is taken by the previous history and forming new norms without affecting quality. The optimum norms may vary from unit to unit and machine to machine. This is because of various reasons like working condition, type of machine, layout of machine, provision of utilities and variations in the quality of the fabric. Therefore every process house has to carry out their own experiments to identify their own optimum processing levels. Once the processing conditions are standardized, then implementation of these conditions during the normal course of production is carried out by keeping required documents. However it is important to select regular inspection checks to ensure that the particular process is going on according to the norms fixed.

'Right First Time' dyeing is now-a-days gaining importance due to competitions within the textile industry. In a manually operated dye house, about 5 to 15 per cent of a typical plant's production has to be re-dyed or discounted because colours didn't come out right the first time. 'Right First Time' concept helps in reducing the cost of process and increases the productivity.

11.1.2. Process control in batch wise dyeing machines

Dyeing machines are designed in different shapes and with different loading capacities to accommodate textile materials in varied forms and qualities. The materials being dyed can be fibre, yarn, fabric, or even garments. In an exhaust dyeing, dyes in the dye bath are gradually transferred on to material, which is thought to be exhausted from dye bath to the substrate. The representative machines designed for batch wise processing include: (1) hanks and package dyeing machines for yarns, and (2) overflow, jet, jig and beam dyeing machines for fabrics. All these are based on (1) circulation of the dye solution through the material, (2) circulation of the material through the dye solution, or (3) circulation of the material and dye solution simultaneously. So in all these machines, process control parameters to be controlled are

(i) colour dissolution

(ii) MLR

(iii) Temperature

(iv) pH of dye bath

(v) Pressure

(vi) Concentration of auxiliaries and chemicals

(vii) dwell time

(viii) washing/soaping conditions, etc.

11.1.3. Process control in continuous dyeing machines

In continuous dyeing, the factors to be controlled include:

(1) Fabric moving speed

(2) Dye liquor condition in padding trough

(3) Padding pressure/liquor pick-up ratio

(4) Even of padding pressure

(5) Pre-drying temperature

(6) Curing and steaming temperature

(7) Evenness of drying, curing and steaming,

(8) Retention time in each unit,

(9) Rinsing units and rinsing conditions.

Fabric moving rate in dyeing covers a broad range. It can be as low as 10 m/m in but also could often exceed 100 m/min depending on the fabric dyed and the efficiency of each unit in the dyeing range. Higher speed always benefits productivity, but i t is m ore important to consider the completion status of equipment involved.

The fixation ratio is never 100%, thus any unfixed dye must be cleaned from the fabric by rinsing and washing to give optimum fastness. Removal of unfixed dye is carried out on continuous washer assembled in the continuous dyeing range.

11.2. Quality Control

Quality control is a set of steps or guidelines designed to guarantee that a product or service meets certain performance standards. Good quality control also helps a company to more efficiently navigate manufacturing and production processes to cut down on mistakes and waste, and maximize profit. It is a program put into place from the very beginning of the textile manufacturing process, starting from the sourcing of raw fibers to the final stages of garment production.

In quality control the final testing of the product is done to meet certain performance standards. For the dyed or printed material, the fastness properties are very important. The following fastness properties are checked

- Fastness to light
- Washing fastness
- Dry-cleaning fastness
- Rubbing (Crocking) fastness
- Perspiration fastness
- Chlorine fastness

Chapter 12

INSTRUCTIONS DURING SHIFT CHANGE OVER

Taking charge of duties while starting of shift:

- Come at least 10 - 15 minutes earlier to the work place.
- Meet the previous shift operator and discuss regarding the issues faced by them with respect to the quality or production or spare or safety or any other specific instruction etc.
- Understand the fabric being processed & process running on the machine.
- Ensure technical details are mentioned on the job card & display in machine.
- Check the next batch to be processed is ready near the machine.
- Check the cleanliness of the machines & other work areas.
- Question the previous shift operator for any deviation in the above and bring the same to the knowledge of the shift superior.

Handing over charge at the end of shift:

- Properly hand over the shift to the incoming operator.
- Provide the details regarding fabric quality & the process running on the machine.
- Provide all relevant information regarding the stoppages or breakdown in the machine, any damage to the material or machine.
- Ensure the next lot to be processed is ready near the machine
- Get clearance from the incoming counterpart before leaving the work spot.
- Report to the shift supervisor in case the next shift operator doesn't report for the shift.
- Report to the shift supervisor about the quality / production / safety issues/ any other issue faced in the shift and leave the department only after getting concurrence for the same from supervisor.
- Collect the wastes from waste bags weigh them & transport to storage area.

Chapter 13

IMPORTANCE OF HEALTH AND SAFETY

- To minimize exposure to hazardous chemicals appropriate personal protective equipment, such as Hand Gloves, Safety Glasses, Gum Boots, Masks, Head cap, etc., should be used.
- Never handle chemicals with bare hands
- Training should be provided on handling of solvents and other harmful chemicals, and how to deal with accidental spills, contact with skin and eyes, and ingestion of chemicals.
- Report any service malfunctions in the machine that cannot be rectified to the supervisor.
- Store materials and equipment at their designated places.
- Minimize health and safety risks to self and others due to own actions.
- Monitor the workplace and work processes for potential risks.
- Do not carry any metallic parts during machine running as there are chances of fire and damage to machine parts.
- Take action based on instructions in the event of fire, emergencies or accidents, participate in mock drills/ evacuation procedures organized at the workplace as per organization procedures.
- Hazardous waste must be disposed of properly in accordance with manufacturer's guidelines (MSDS) and national policies.
- Exit passageways and stair cases must never be blocked with obstacles and all stairs should have hand rails.
- Employees should be given access to safe drinking water as well as a clean area for meals.
- Emergency exit doors should never be locked.
- Proper lighting and ventilation need to be ensured and machinery must be well maintained to avoid accidents.

- Sufficient fire extinguishers should be made available and signs should be placed in prominent places so that people are aware of their presence.
- There should also be signs saying “No Food and Drink’ in areas such as the laboratory, store room and factory floor, and any other areas where it is not safe to consume food.
- Hazardous chemicals should be clearly marked in an appropriate language and with clear symbols that people have to be trained to recognize and understand.
- Sins should be placed near inflammable substances stating that it is not permitted to smoke or have open fires.