Functional finishes

Contemporary wool dyeing and finishing

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What are functional finishes?

- These are wet processes used to produce special effects on fabrics or to improve specific properties.
- Many of these effects are required to increase the customer appeal of products or to augment fabric properties for particular end-uses, such as outdoor wear or protective clothing.

Topics

- Softening handle
- Shrink-proofing mechanisms
- Shrink-proofing methods
- Zero AOX shrink-proofing
- Enzyme technology
- Flame retardation
- Insect proofing
- Easy-care pure wool garments
- Waterproofing
- Laminated and double face fabrics
- Stain resist treatments
- Sanitising
- Plasma treatments
- Nano-finishes
- Optim fibre production
- Garment setting
- Reducing static
- Future trends

Softening handle

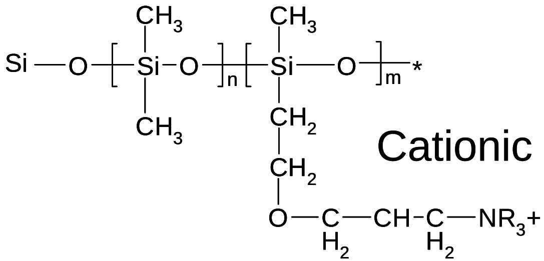
- Softeners lubricate the warp and weft yarns of woven fabrics so that they slip more easily over each other.
- Softened fabrics bend relatively easily in the hand and consequently feel softer.
- Some softeners can also decrease the coefficient of friction between fingers and fabric. These slippery softeners tend to leave a tangible residue on the fingers.
- Softeners range from non-ionic mineral oils, silicone oils, cationic fatty compounds and silanes.

Softeners for wool

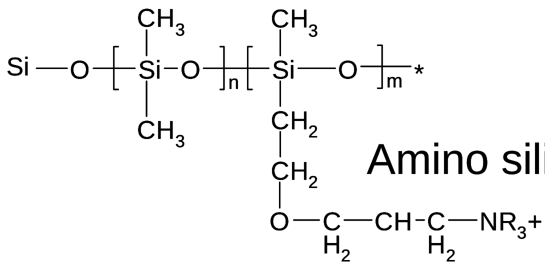
- **Cationic products** (such as cetyltrimethyl ammonium chloride and disteryldimethyl ammonium chloride) are **substantive** to wool and have a degree of permanence.
- **Silicones**, including amino, nonionic, selfcrosslinking and cationic types are now widely used. They can be hydrophobic or hydrophilic. **Amino silicones** often have **good affinity for wool**. They are often in microemulsion form (e.g. Basolan MW Micro)
- They can be **applied by exhaustion** (subject to compatability) and by immersion followed by drying.

$$H_3C-(CH_2)_{15}-\overset{+}{N}-(CH_3)_3 \quad Cl^-$$

CTMAC



Cationic silicone



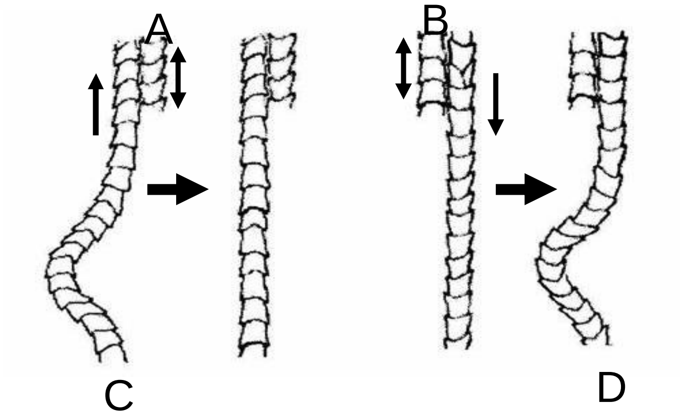
Amino silicone

Shrink-proofing of wool

Wool can be made shrink-resistant in two different ways:

- Subtractive processes
  - the surface scales on the fibres are modified – usually by oxidation
  - polymers are often applied after oxidation to improve handle and compensate for weight loss
  - only suitable for **loose fibre or top**.
- Additive processes
  - the fibres can be bonded together using a polymer
  - only suitable for **fabric**.

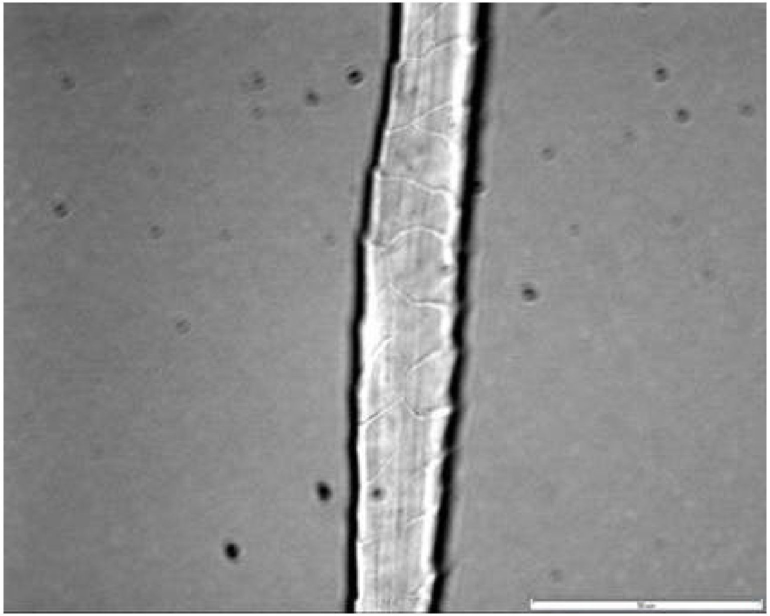
The ratchet mechanism of felting

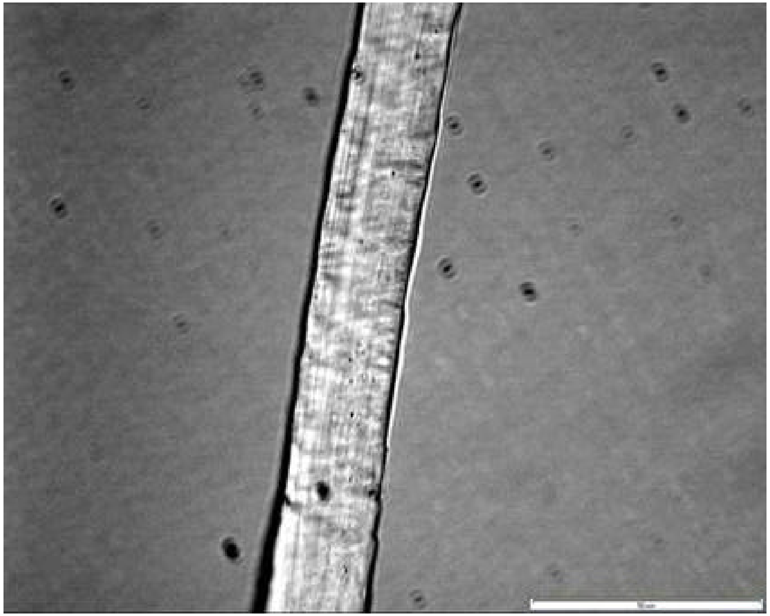


As fibres A and B move up and down, fibre C moves up and fibre D moves down.

Shrink-resistance is achieved by reducing the differential friction between fibres, by damaging or covering the scales, or by bonding the fibres together so they cannot move during washing.

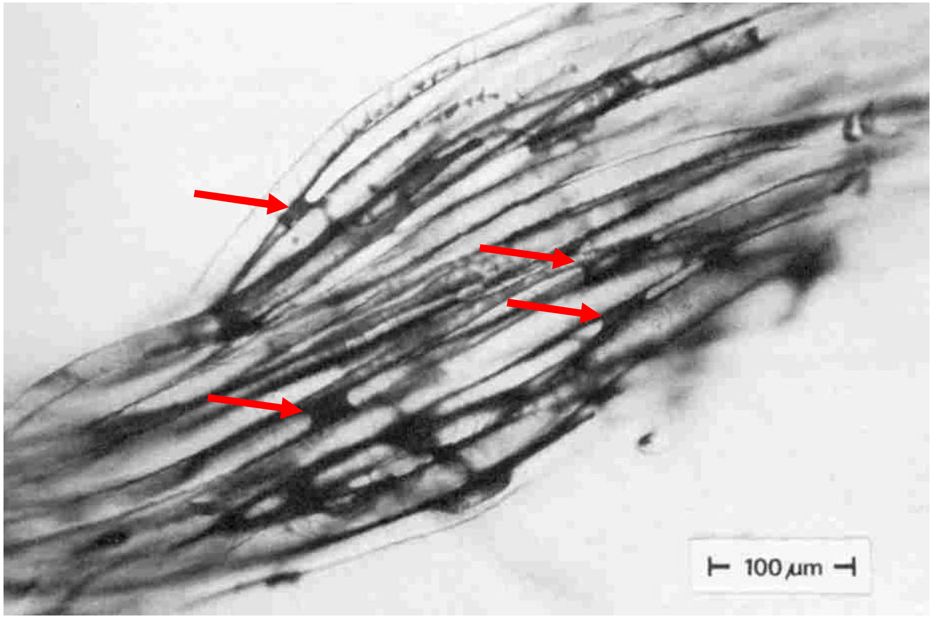
The effect of chlorination





Scales can be seen on the surface of the untreated fibre on the left, but they are no longer visible on the chlorinated fibre on the right.

Shrink-proofing mechanism of additive processes



This picture shows Synthappret BAP stained with C I Acid Violet 75. Inter-fibre bonds of cured resin can be seen in the yarn removed from a treated fabric.

Degradative shrink-proofing processes

- In degradative processes, **the scales are partly or totally disolved.**
- Wool is first **treated with an oxidising agent**.
- **Oxidised protein is then removed** from the fibre surfaces by washing.
- **Oxidation** is most commonly carried out **by chlorination** using a product such as Basolan DC or Basolan 88 (BASF).
  - Basolan DC is a form of DCCA (sodium salt of dichloroisocyanuric acid).
- **Permonosulphuric acid also can be used**. It is more ecologically acceptable than chlorine, but it is less effective.

Fabric chlorination with DCCA

Batch treatment

- Fabric is run for 10 minutes cold with:
  - 1-2% Leophen M (BASF) and
  - 3% acetic acid (60%) at
  - pH 3.5-4.5.
- Then treated for 30 to 45 minutes cold in the same bath with up to 3.0% Basolan DC at pH 4 to 4.5.
- Unreacted chlorine is removed from the fabric by treating for 10 minutes cold in the same bath with 2.0% sodium metabisulphite.
- Then the bath is dropped and the fabric rinsed.

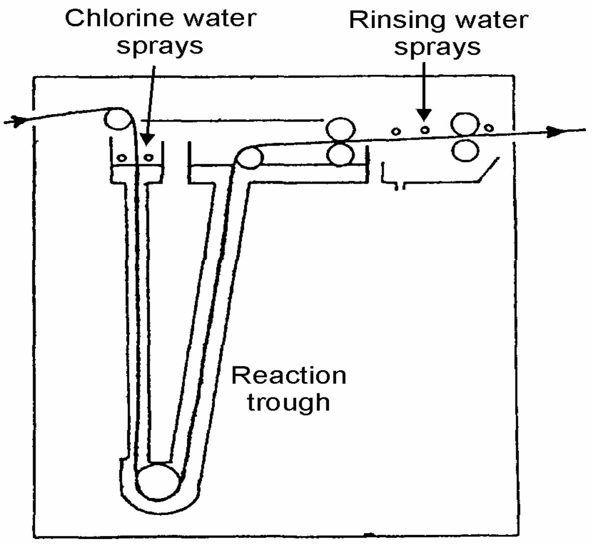
Fabric chlorination with DCCA

Continuous treatment

- Fabric is padded with a liquor containing:
  - 10-30 g/l Basolan DC (0.6-3.0% o.w.w.) and
  - 5 g/l Laventin CW (BASF) (a nonionic wetting agent which is stable to chlorine) at
  - 60-80% pick-up.
- The fabric then passes to anti-chlorination and rinsing stages.
- Efficient ventilation is required to exhaust chlorine gas emitted during the process.

Chlorination of fabric using a Kroy machine

- An aqueous **acidic solution of chlorine** is sprayed onto fabric at the start of its passage into a very deep, narrow trough and reaction occurs very rapidly as the fabric passes through the machine.
- **After chlorination**, the fabric is passed to an open-width washer where it receives **anti-chlorination, neutralisation and rinsing** treatments.
- Efficient **ventlation and scrubbing systems are required** to remove chlorine gas from the vicinity if the chlorinator.



Polymer application after surface oxidation

- After the oxidation treatment, **a soft, cationic polymer** such as Basolan SW or Basolan MW Micro (BASF) then **may be applied** to the wool.
- **Padding or exhaustion** techniques can be used.
- **Equivalent systems** are available including, e.g. the Dylan GRB process from Precision Products (Textiles) Ltd.
- A similar **exhaustion process for knitwear** has also been developed, but in this case oxidation is performed with potassium permonosulphate (Caroat) before Basolan SW is applied. This process has the advantage of being halogen free.

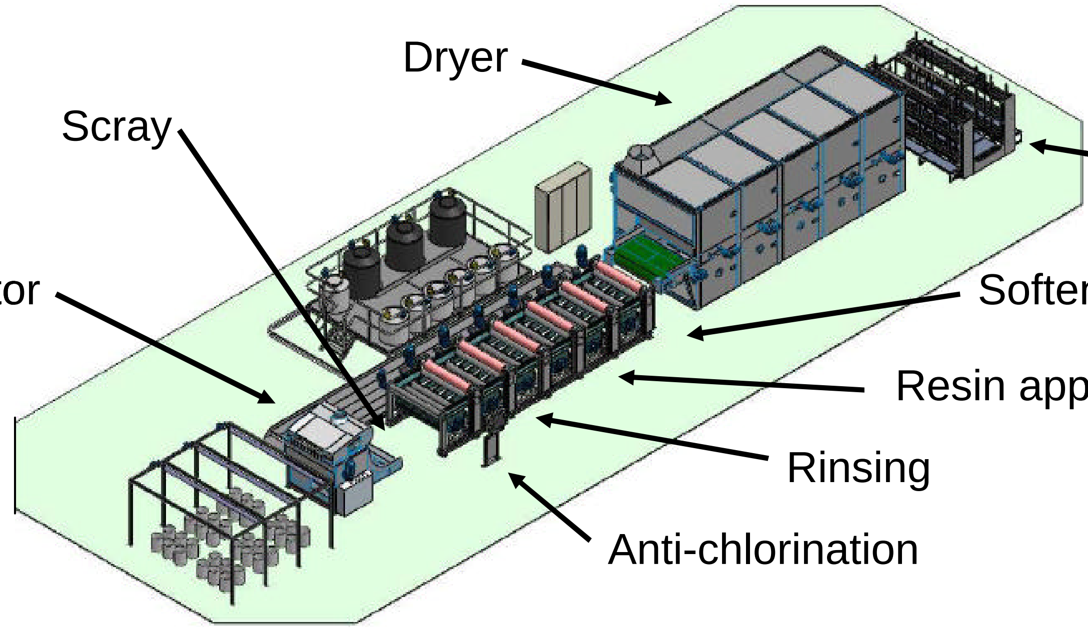
Chlorine-Hercosett treatment

- First the **wool is oxidised using chlorine** dissolved in water (about 1-2% o.w.f.). A special applicator is required to ensure that the treatment is as even as possible.
  - Chlorine can be generated in situ from sodium hypochlorite and sulphuric acid, or DCCA, or chlorine gas may be dissolved directly in water (Kroy chlorinator).
  - The **treatment is extremely rapid** and mainly confined to the fibre surface. It takes place in less than 10 seconds.
  - Chlorination equipment includes modified suction backwash drums, pad mangles and Kroy chlorinators.
  - The chlorination treatment increases the surface energy of the fibre and gives it a negative charge so that Hercosett 125, a polyamide epichlorhydrin type polymer, applied in a later bowl, can spread evenly along the fibre surface.

Chlorine-Hercosett treatment

- Following chlorination, the wool receives an anti-chlorination treatment with a reducing agent such as sodium bisulphite.
- Rinsing comes next.
- The cationic polymer, Hercosett 125, is applied in the next bowl.
- A silicone softener is applied last. This partly compensates for the deterioration in handle.

Chlorine / Hercosett treatment



- The process is carried out in a modified backwasher and can treat up to 45 slivers of wool top yielding over 500kg of treated wool per hour.
- Around 30 million kg of wool are treated by this process each year.

Typical set-up and running conditions for a continuous chlorine/Hercosett system

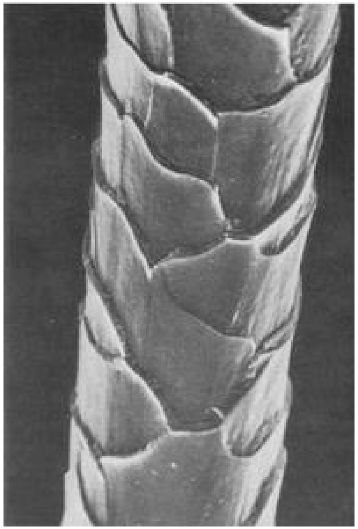
Bowl	Temp (°C)	pH	Make-up	Feed
(1) Chlorination	10-15	1.5	0.3 g/l available chlorine 5.0 ml/l sulphuric acid 2.5 ml/l wetting agent	1.8-2.2% chlorine [a] 0.02% solids wetting agent
(2) Anti-chlor	40	9.0	5.0 g/l sodium bicarbonate 5.0 g/l sodium sulphite	0.8% sodium sulphite sodium carbonate to pH 9.0 ±0.3
(3) Rinse	30-40	-	water	300% water at 30°C
(4) Polymer	35	7.5	10 g/l sodium bicarbonate 5 g/l Hercosett 125 solids	0.2% Hercosett 125 solids
(5) Softener	40-45	7.0	5 g/l sodium bicarbonate 2.5 g/l softener solids 7.5 ml/l lubricant	0.15% softener solids 0.4% lubricant solids

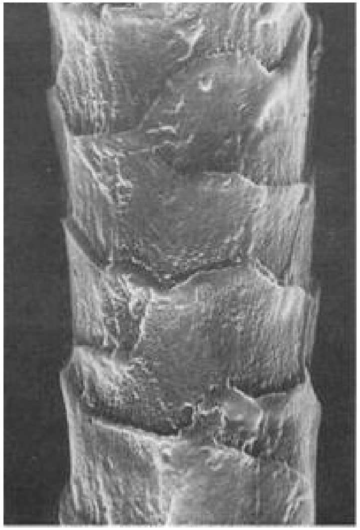
[a] 1.8% for wool coarser than 25 µm, 2.2% for wool finer than 20 µm.

How the chlorine / Hercosett process shrink-resists wool

- The chlorination treatment shrink-resists the wool by partly dissolving the edges of the cuticle cells.
- The polymer restores some of the weight lost.
- During washing, the polymer swells to 10 times its normal thickness in water and this aids the shrinkproofing effect by preventing the fibres from moving relative to each other during washing.

Untreated





Treated

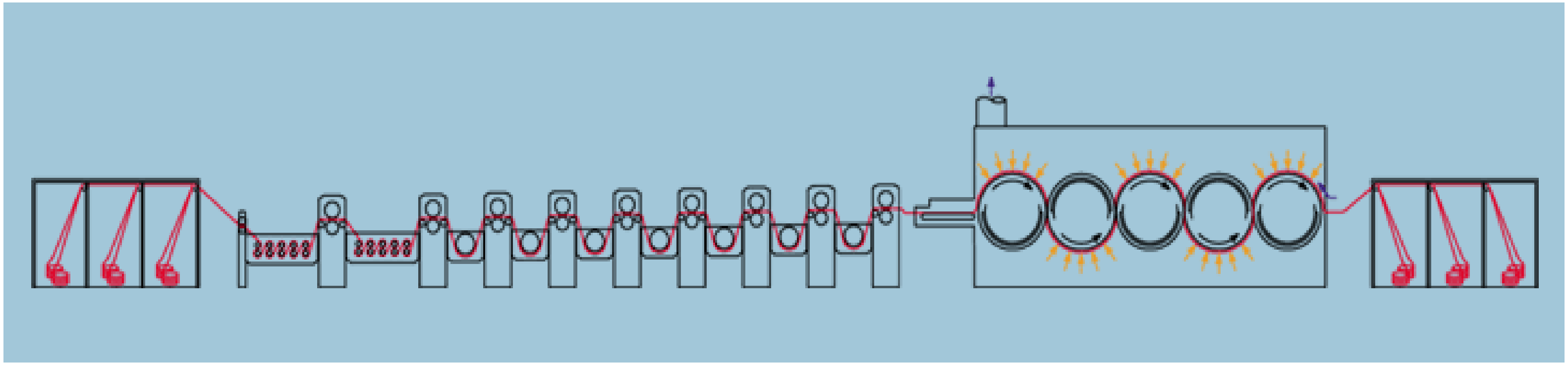
Problems with the chlorine / Hercosett process

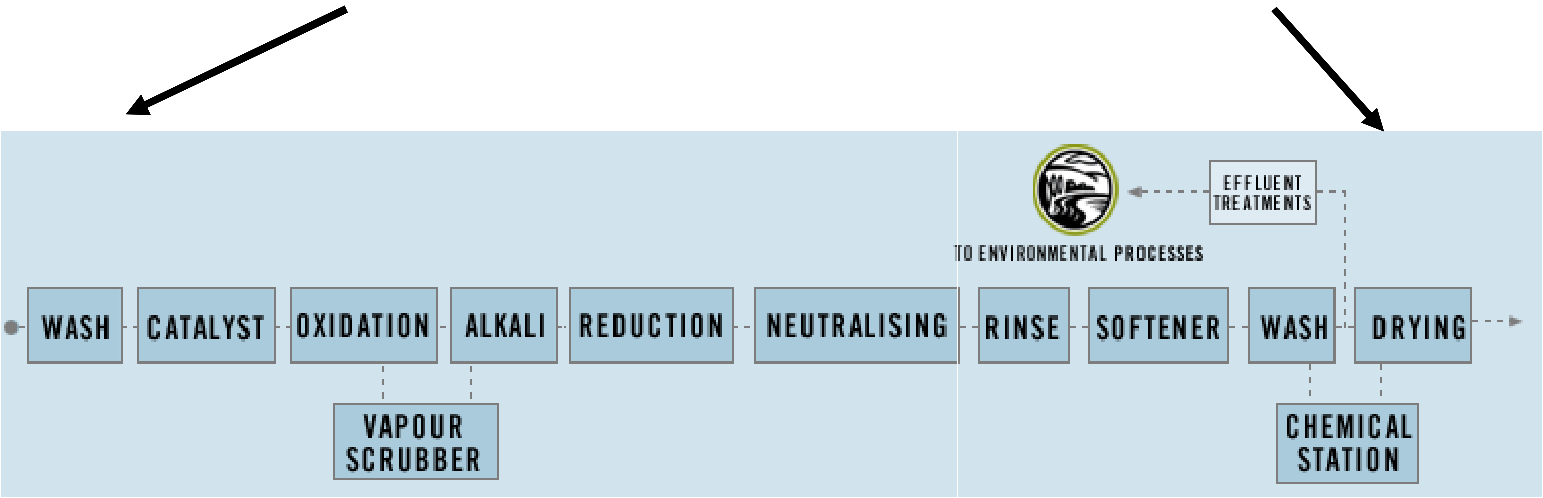
- Rapid dye strike requires modified dyeing methods.
- Only dyes with highest wet fastness properties can be used to colour the fibre.
- Effluent from rinsing contains chlorinated residues, because of the chlorination step and because Hercosett 125 contains chlorine, hence problems with AOX.

Zero AOX top shrinkproofing

- In principle, **it should be possible to replace the chlorine** oxidation step with an oxidant which does not contain chlorine and the resin with a chlorine-free alternative.
- Unfortunately, **no oxidant has been found** which is as fast-reacting and effective as chlorine.
- The most promising alternative to chlorine is **permonosulphuric acid** (PMS).
- **Processes using PMS and silicone resins** include the Sirolan ZAOX process, the Dylan Plus process (Precision Processes) and the Andar chlorine free shrink-resist process.
  - Advantages included **good colour and soft handle**.
  - Disadvantages are that **reproducibility is difficult** to maintain and there can be poor cohesion between the treated fibres which causes **difficulties in gilling and spinning.**

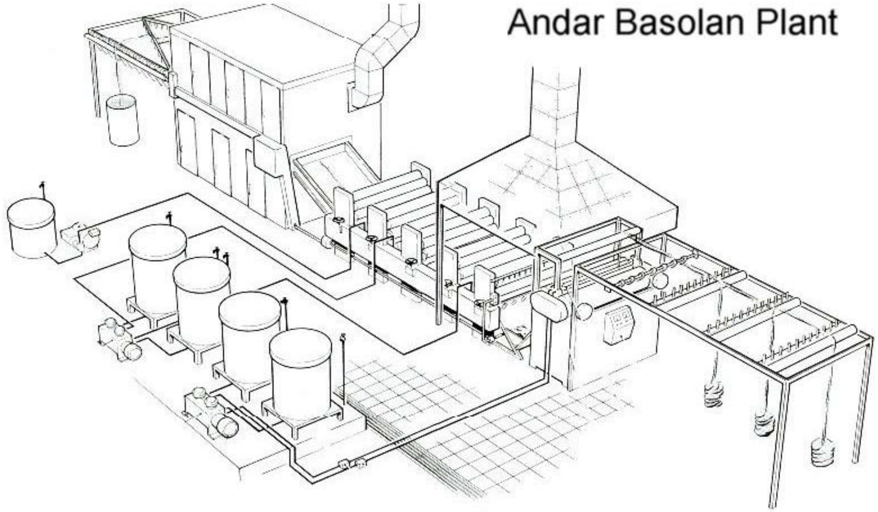
Andar chlorine-free top shrink-resist process





Basolan soft handle processes

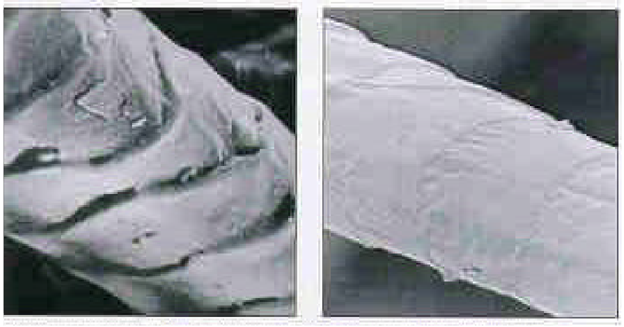
- This process uses similar processing machinery to the chlorine/Hercosett process but with fewer backwash bowls.
- Chlorination is carried out with Basolan® 88 over a longer time in an Andar Applicator.
- After chlorination, the tops pass through neutralisation, rinsing and softening bowls prior to drying.



Andar Basolan Plant

Soft lustre treatment

- A continuous chlorine/Hercosett plant can be used, but the concentration of **chlorine** used in the chlorinator is increased (to around **4% o.w.f**.), so that the whole of **the scale structure will be removed** from the fibres.
- The Hercosett **polymer application is omitted**.
- A hydrophobic **silicone softener is applied** to counteract changes in handle.
- This makes the **fibres smooth and lustrous**, with an appearance similar to that of silk fibres.



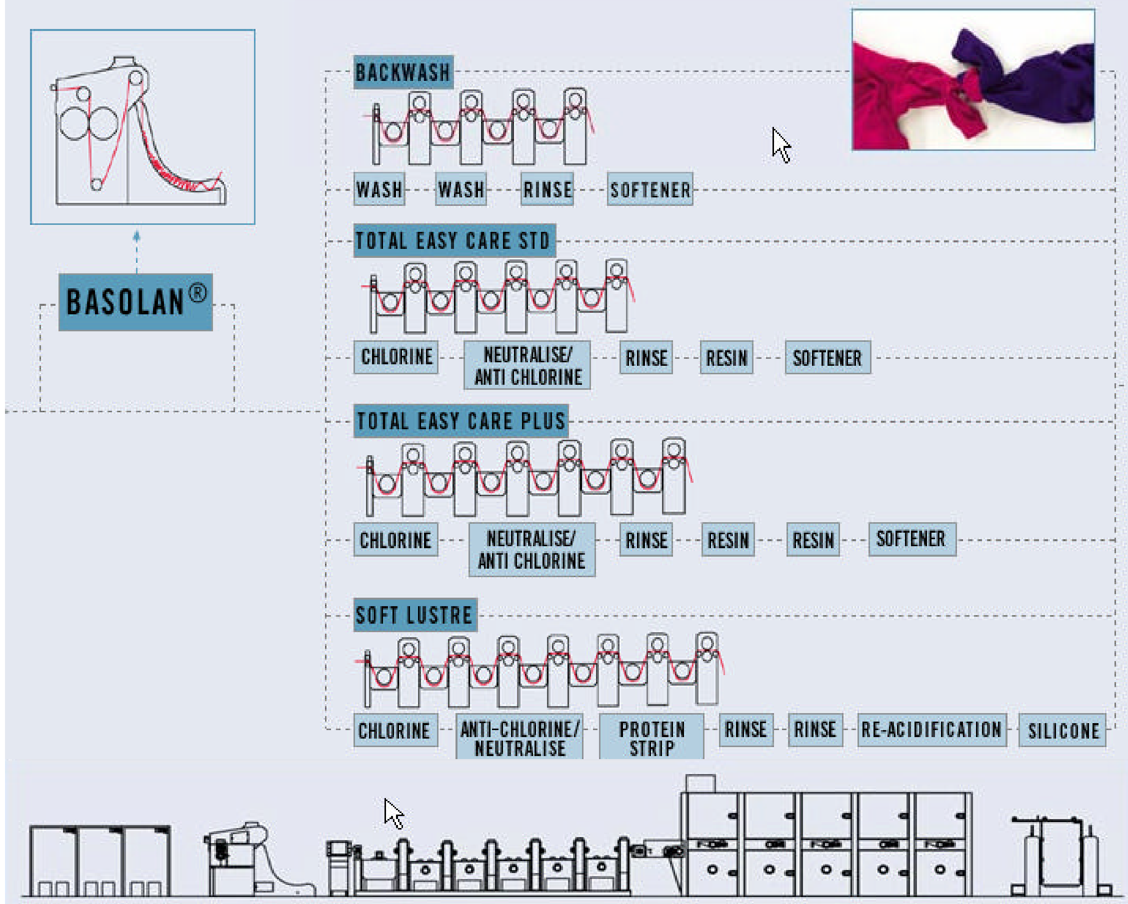
Untreated Soft lustre treated

Consequences of the soft lustre treatment

- The wool becomes **weaker**.
- The treated wool feels **softer** by 2 to 3 microns, and it meets standards for machine washing performance.
- Garments made from this fibre are **ideal for next to skin wear** and have found major success in the Chinese underwear market.

Superwash equipment from Andar

BACKWASH - cleaner brighter tops with low residual ash.
BASOLAN - natural softness, good colour, brighter pastels and improved spinning performance.
TOTAL EASY CARE STANDARD - to render wool apparel products fully machine washable.
TOTAL EASY CARE PLUS - to provide fully machine washable and machine dryable fabrics.
SOFT LUSTRE - to improve the softness comfort and lustre of Easy Care wools.



Batch shrink-resist treatments for knitwear

- Examples are the Simpl-X process from PPT and Basolan DC/MW from BASF.
- Both processes involve pre-oxidation of the fibre with either chlorine (Basolan DC), or peroxymonosulphuric acid (Simpl-X).
- After neutralisation, the fibre is treated with a substantive silicone softener to enhance the handle.
- The garments can meet TEC standards of performance for washability.
- The treatments are ideal for woollen-spun garments with a milled finish.

- The garment treatments are normally performed on up to 200kg batches in side-paddles, which are capable of gentle agitation of the garments.

Batch shrink-resist treatment of knitwear

Dylan GRB Process

- The treatment is carried out on woolen or worsted garments in a side paddle at a liquor ratio of 30:1.
- There are four steps to this process:
    - preparation
    - chlorination
    - neutralisation
    - polymer addition.

Dylan GRB Step 1 - Preparation

Woollen spun:

1. Scour
   - Fill bath with water at 40°C and add goods
   - 3-6% of Millscour XBN
   - run paddle for 5-10 minutes and drain.
2. Mill
   - Fill bath with water at 40°C
   - 1-3% of Millscour XBN
   - run paddle until required milling is achieved, usually 5-45 minutes
   - drain
   - rinse warm 3-5 minutes and then cold 3-5 minutes.

Dylan GRB Step 1 - Preparation

Worsted spun:

1. Anticockle
   - Fill bath and bring to boil before garments added
   - add garments slowly so boil is maintained; leave to soak for 10 minutes
   - only operate paddle for 10-20 seconds periodically; cool to 40°C over 5-10 minutes by adding cold water with the paddle running.
2. Scour
   - Fill bath with water at 40°C
   - 1-3% of Millscour XBN
   - run paddle for 5-10 minutes and drain
   - rinse cold 3-5 minutes.

Dylan GRB Step 2 - Chlorination

- Fill bath with cold water (20°C).
- Set paddle speed at 12-14 rpm.
- Add 0.5% Millscour XBN and 3% formic acid.
- Run bath for 3-5 minutes and check pH is 3.0-3.5.
- Increase paddle speed to 14-18 rpm.
- Drip feed a solution of x % DCCA dissolved in cold water over 20-30 minutes.
- Reduce paddle speed to 12-14 rpm
- Continue until no chlorine is detected with starch/iodine paper.

Amount of DCCA:

- Shetland 1.5-2.0%
- Lambswool (woolen) 2.0-3.0%
- Botany 3.5-4.0%
- Lambswool (worsted) 4.0-4.5%.

Dylan GRB Step 3 - Neutralisation

To the exhausted bath from chlorination:

- add 5% sodium sulphite (anhydrous)
- adjust pH to 6.0-6.5 with sodium carbonate
- run for 20 minutes then drain bath
- rinse cold for 3-5 minutes.

Dylan GRB Step 4 - Polymer addition

- Fill bath with cold water and set paddle speed to 14-18 rpm.
- Add 1 % acetic acid.
- Check pH is 5.0-5.5.
- Add 2.0% Polymer GE, diluted 10 times with water. Steadily over a period of 10 minutes.
- Reduce paddle speed to 12-14 rpm.
- Run for 5 minutes.
- Warm bath to 40°C and run for a further 15-20 minutes.
- Add 1-3% cationic softener, if required.
- Add 0.5-2.0 ml/l hydrogen peroxide.
- Run for 10 minutes and drain.

Additive shrink-proofing processes

- Soft, durable, self-crosslinking polymers are applied to fabric by pad-dry processes.
- Machine washable fabric is obtained.
- The polymers form inter-fibre bonds between the fibres and prevent them from moving during washing.
- Two different types of polymers may be used:
  - reactive polyisocyanates
  - reactive silicones.

Reactive polyisocyanate polymers

- **Synthappret BAP** (Bayer) is a 50% solid solution of a reactive, water-soluble derivative of a polyisocyanate.
  - Application is by padding on untreated fabric under slightly alkaline conditions and curing is achieved by high temperature drying.

- A better treatment is to **mix 1-2% Synthappret BAP with an equal amount of Impranil DLH** (Bayer), and 3-5 g/l sodium bicarbonate.
  - Handle is softer.
  - Shrink-resistance is slightly improved.
  - Cost is reduced.

- Other products which are chemically similar to Synthappret BAP are Braxan WF (Ciba-Geigy) and Protolan 367 (Rotta). The polyurethanes recommended for co-application with Braxan WF and Protolan 367 are Dicrylan PMC (Ciba Geigy) and Rotta 215 Finish (Rotta) respectively.

Reactive silicone polymers

- The Ultratex process of Ciba is based on a reactive silicone elastomer Ultratex ESB or Ultratex ESC.
- An aqueous solution of the polymer containing 3-5% o.w.f. of polymer solids and a small amount of catalyst Ultratex EW (1/30th of the amount of silicone elastomer) is padded onto untreated fabric which is then dried in the normal manner.
- Approximately seven days at room temperature are required for the polymer to cure fully. It is imperative that the fabric is stored in full width during this period, preferably in a roll, to prevent memory creasing from occurring.
- The smooth, soft, slick handle obtained is typical of a silicone finish.

Enzyme technology for shrink resistance

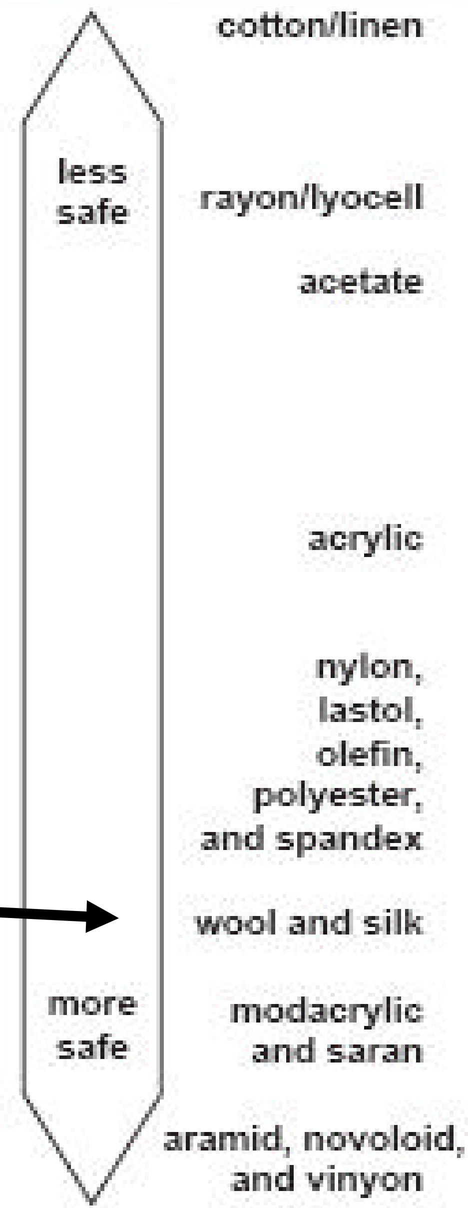
- **Protease enzymes can degrade the cuticle of the wool fibre** and impart a degree of shrink resistance (e.g. Petry Lanazyn process)
- **Pre-oxidation of the fibre surface is usually required** to enable the enzyme to gain access to the fibre protein in the cuticle.
- Enzyme processes tend to require **long treatment times** at relatively low temperatures to create a suitable degree of shrink resistance. The processes are therefore not very efficient.
- A **disadvantage** of enzyme treatments is the **weakening of the fibre** but this can be used to good effect during piece-dyeing of worsted-spun knitwear where surface fibre generation or facing-up is unwanted.
- Surface fibres tend to be preferentially treated and weakened so they drop off the surface thereby giving dyed goods a **clean appearance** and **enhanced anti-pilling performance**.
- The most obvious **benefit** of enzyme-based processes is that they can have **minimal impact on the environment**.

Flame-retardancy

- Numerous accidents, some fatal, arising from garments catching alight have resulted in the development of flame retardant finishes.
- Some fibres such as cotton, linen, viscose, ignite fairly readily, and even if the flame is extinguished may leave an afterglow which can re-ignite the fabric.
- Synthetic fibres melt and may cause very severe burns.
- Wool fibres burn slowly and do not support combustion if the fabric is removed from the flame.

Wool is amongst the safer fire-resistant textiles

- Wool is difficult to ignite, burns slowly and may self extinguish.



The need for flame resistant wool

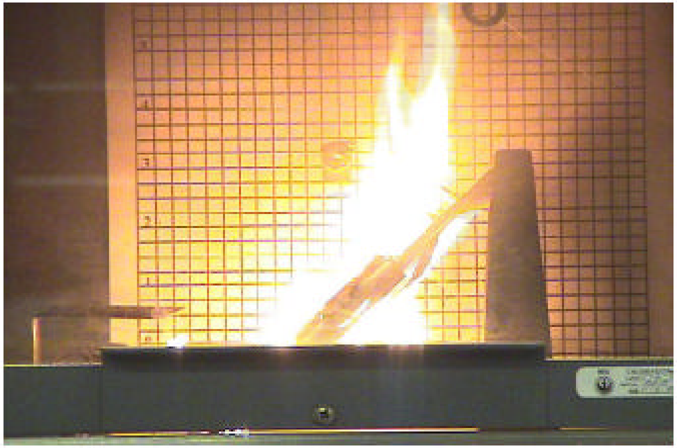
This is limited to niche product areas:

- apparel fabric for use in uniforms and protective clothing for racing car drivers, firemen and foundry workers
- upholstery for aircraft and public buildings.

- Protective clothing worn by CFA firefighters consists of yellow overpants, a blue cotton T-shirt, a fire retardant black pure wool jacket, yellow shoulder protectors and yellow reflective fluoro strips on the jacket.

Flamability tests

- To be classified as flame retardant, fabrics must pass one or more tests required by the relevant authority.
- The general test format is as follows:
  - Fabric samples of a standard size must be held vertically, horizontally, or at 45º or 60º to the horizontal direction
  - A flame of a designated size and temperature must be applied to the end of the sample for a certain time.
  - The burning behaviour of the sample is then observed.



Five-second flame exposure, 45º burning test.

- Flame retardant garments do not allow continuation of burn. When exposed to the initial fire / heat contact, the garments will either not support combustion or self-extinguish upon removal from this flame/heat source.

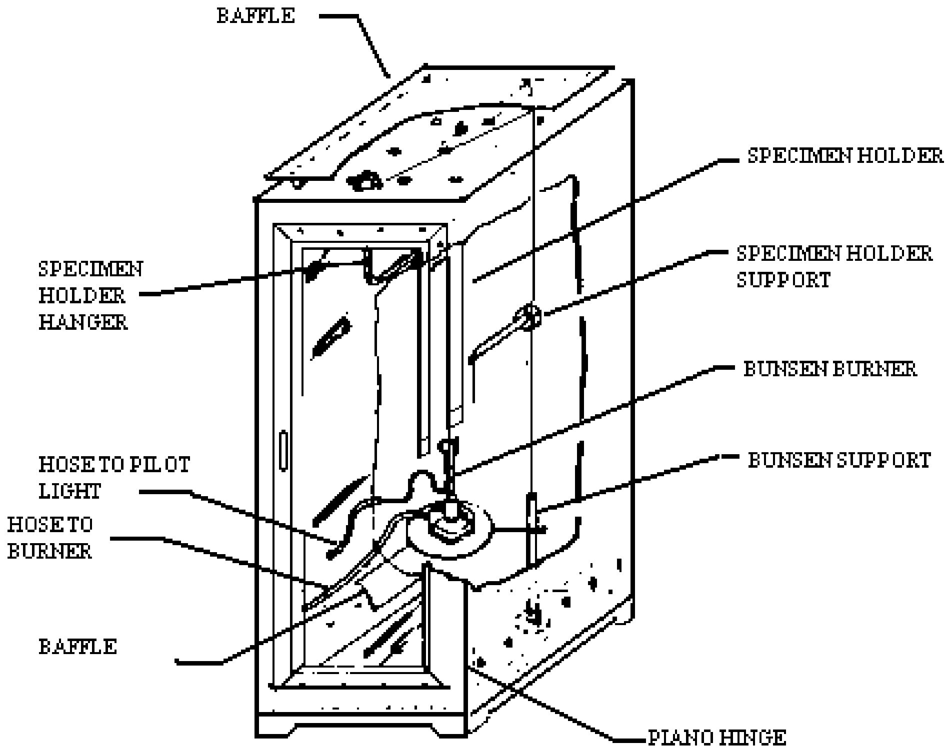
The 12-second vertical Bunsen burner fire test

This test is widely used for wool products.

To pass this test:

- any flames present on the 75 mm by 305 mm fabric sample must self-extinguish within 15 seconds after the fire source has been removed
- the burn length shall not exceed 203.2 mm
- Any material that melted and fell to the base of the cabinet shall not burn for more than 5 seconds.

Vertical flammability tester



Flame retardant finishes for wool

- Zirpro (IWS).
- Zirconium and titanium complexes.
- Pyrovatex CP (Ciba).
- Methoxylated phosphonanide.
- Aflammit (Thor).

Of these, **the best known** and most widely used is the **Zirpro process**.

The major disadvantage of the Zirpro process is its use of heavy metal compounds which are nor very environmentally acceptable.

Zirpro flameproofing treatment for wool

- Developed by International Wool Secretariat (IWS) in 1977.
- Good fastness to drycleaning.
- White and pale shades were not altered by the FR finish.
- Zirconium and/or titanium complexes are exhausted onto wool at acidic pH.
- Enables many protective wool products to meet test requirements.

Zirpro low-smoke, flame proofing treatment

	Upholstery	Carpets
Formic acid (90%)	**10.0**	**10.0**
Citric acid monohydrate	**6.0**	**8.0**
Potassium hexafluorozirconate	**3.5**	**2.3**
Zirconium acetate solution (22% ZrO_2)	**7.7**	**10.0**

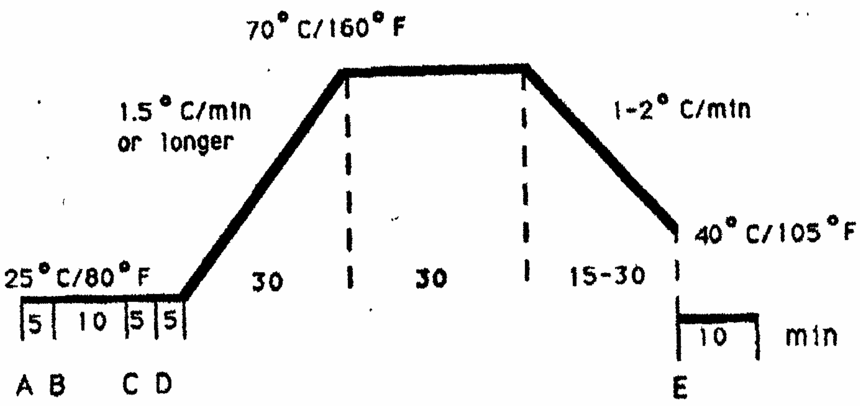
Step A:
- 0.1 g/1 non-ionic wetting agent, if required.

Step B:
- 10 % formic acid, *x* % citric acid.

Step C:
- *y* % potassium hexafluorozirconate (dissolved).

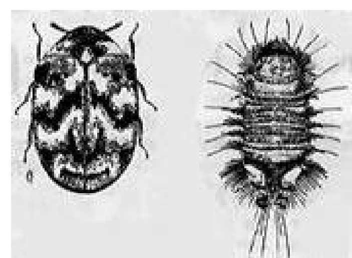
Step D:
- z % zirconium acetate solution (diluted with cold water) (bath will become cloudy; it will clear as the temperature reaches 45-50°C).

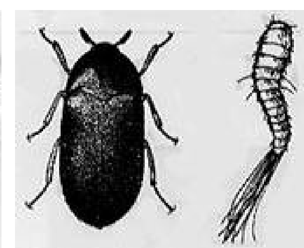
Step E:
- rinse for 10 minutes in cold water (do not use overflow rinsing).



Insectproofing

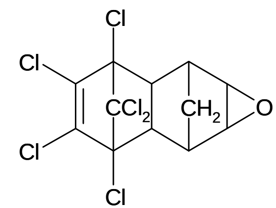
- Textile products made from proteins, including animal fibres, hair, feathers, furs, and leather, can be attacked by the larval forms of certain insects which can digest crosslinked proteins.
- The commonly encountered wool eating insects in Australia are the case-bearing clothes moth (*Tinea pellionella*), the common clothes moth (*Tineola bisselliella*), the furniture carpet beetle (*Anthrenus flavipes*) and the black carpet beetle (*Attagenus piceus*).
- Particularly large populations of the case-bearing clothes moth occur in areas with warm climates around the world.
- Only the larval form of the insect feeds on textile products.



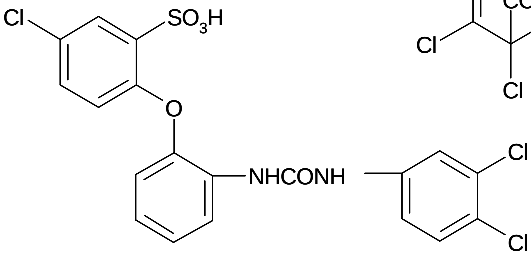


Mothproofing treatments

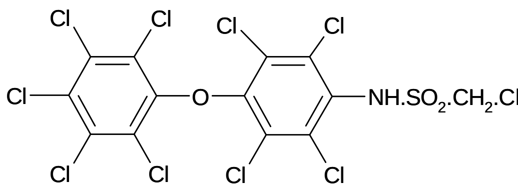
- Chemical compounds designed to kill the wool-eating larvae are applied to wool.
- Chlorinated aromatic compounds such as DDT and dieldrin became widely used, but in the face of mounting environmental evidence against this type of compound, they were replaced by compounds such as Mitin FF, Eulan U33 and Eulan WA New (Bayer). These compounds were chlorinated products but they were less persistent in the environment and not as toxic to higher animals.



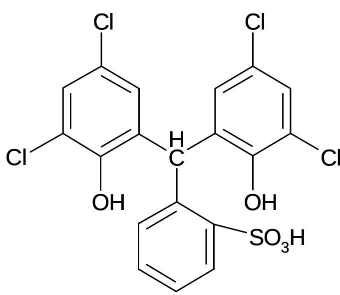
Dieldrin



Mitin FF



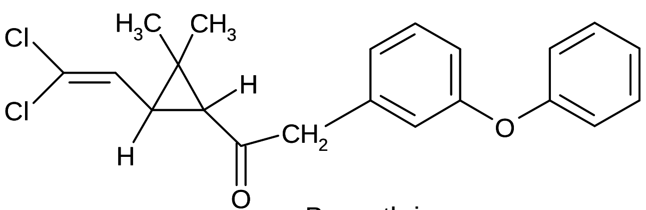
Eulan U33



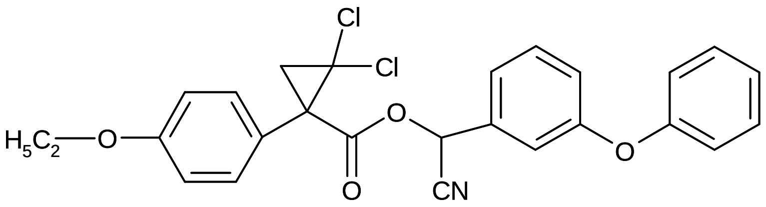
Eulan WA New

Modern mothproofing chemicals

- The latest products are synthetic pyrethroids, related to the natural product pyretherin.
- Examples are Permethrin (Ciba) and cycloprothrin (Cyclosal), (Nippon Kayaku).
- Pyrethroids also may have problems, particularly when the effluent from a treatment plant is discharged into a river, because of acute toxicity to small aquatic animals.
- Application methods and effluent treatments need to be employed to minimise discharges to the environment.



Permethrin



Cycloprothrin

How insectproofing finishes are applied

- Insect proofing chemicals can be applied by dyebath exhaustion, or by foam application, dipping, spraying or padding followed by drying. Padding treatments are most common.
- The minimum effective concentration for pyrethroid compounds on wool is usually between 0.01 and 0.02%, however, in practice the actual applied levels are usually higher to provide a safety margin.
- In the future, the application methods of choice will produce minimal discharges to the environment.

Easy-care wool garments

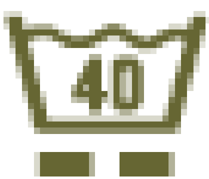
- Easy-care garments must retain their appearance with little ironing after repeated machine washing and tumble drying.
- This can only be achieved if the fabric has very low levels of shrinkage, the fabric stays smooth and without wrinkles, seams remain flat and without pucker, and any creases or pleats remain in place.
- With pure wool garments, the main impediment to easy-care performance, is the difficulty of maintaining sharp creases and flat seams after laundering.

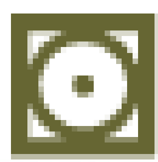
Processing and technical requirements for easy care garments

- Shrink-proofing.
- Permanent flat set.
- Permanent setting of creases and seams in a garment.
- Choice of sewing threads, zippers, and interlinings that do not introduce puckering during laundering.
- Durable buttons and fasteners.

Easy care performance of wool blends

- Easy-care performance is easiest to obtain in wool/polyester garments with a blend level of around 60/40.
- Appropriately constructed medium weight worsted fabrics at this blend level are shrink-resistant.
- Garments may be steam pressed to temporarily set the wool component and then heated in an oven to heat set the polyester.
- The heat set polyester then permanently maintains the creases and flat set in the garments.
- Garments are often machine washed in a bag and drip dried to prevent the creases from opening (Marks and Spencer, UK; Berkeley Apparel, Australia).





Pure wool easy care

- Delayed cure, polymer based, proceses have been used in a limited way for many years.
- In the most recent process, fabric is first padded with Synthappret BAP and then dried at low temperature to prevent curing of the polymer.
- After making up, garments are steam pressed to cure the polymer and stabilise the shape.
- The pressed garments are then hung up and steamed for some time at atmospheric pressure or for a short time in an autoclave.
- The polymer shrinkproofs the wool and holds the garment in its final shape, with the seams and creases closed, while the wool is permanently set.

EASY Care & Wear WOOL

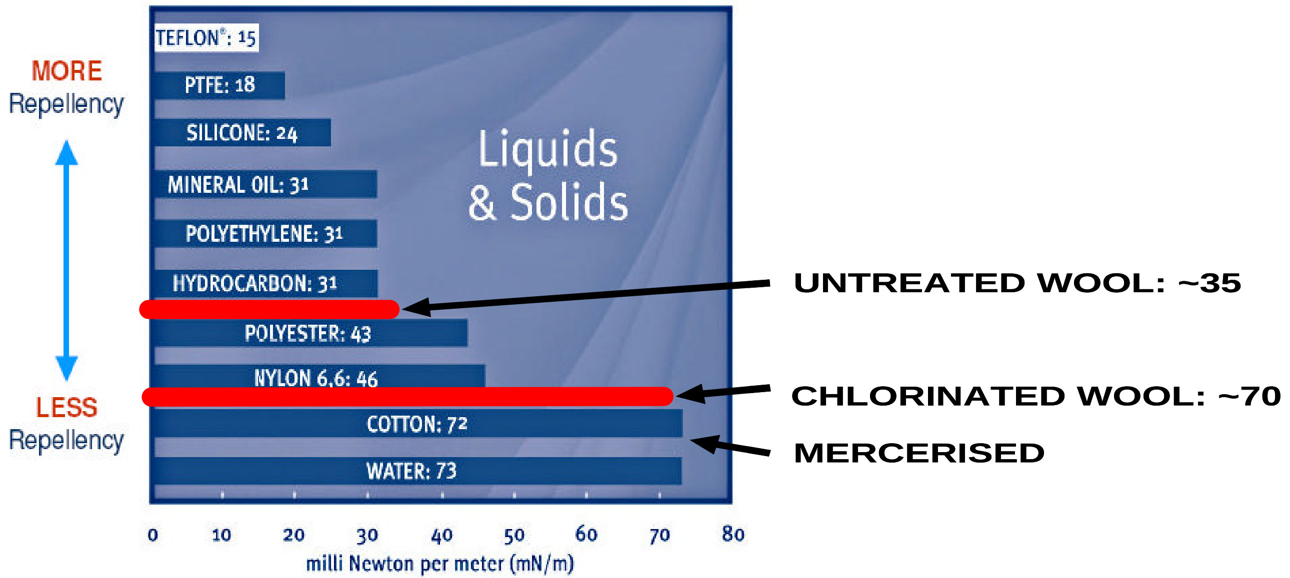
TOTAL EASY CARE WOOL

The surface energy of wool fibres

- Untreated wool fibres have a very thin, waxy, lipid coating on the surfaces of the cuticle cells.
- The surface energy of wool fibres is lower than cotton, nylon or polyester and is comparable with that of polypropylene.
- This means that water droplets on the surface of wool fabric will bead and roll off before being absorbed into the fabric.
- This allows time for liquid spills to be wiped off before they can cause permanent staining.

Repellency rating

Surface tension values of liquids and surface energy values of solids.



- **Oxidised wool has a much higher surface energy than untreated wool and is easily wet by water.**
- **Shrink-resistant wools may require treatment to be water repellant to any degree.**
- **Surface energy can be lowered by treating with a silicone or flurocarbon polymer.**

Waterproofing

Properties of waterproof and water-repellent fabrics

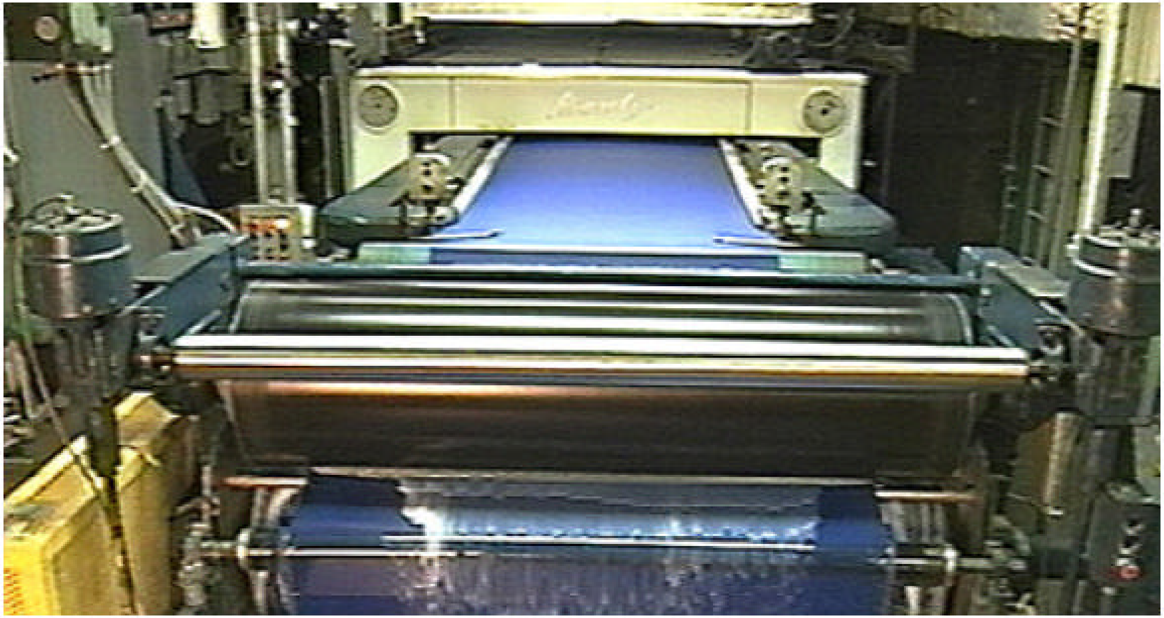
Fabric properties	Waterproof	Water-repellent
Pores	Filled	Open
Water vapour permeability	None - low	Low - high
Air permeability	None - low	High
Water penetration	Highly resistant	Somewhat permeable

Waterproofing

- **Wax** mixtures are applied from solvent solutions or as aqueous emulsions containing aluminium or zirconium salts. The waxes were pliable at normal temperatures and were well suited to protective clothing. However, the treatments were **not fast to cleaning**.
- **Silicones** are the most widely used water repellents. They consist of polymers based on a siloxane chain carrying groups of differing reactivity and they can be applied from organic solvents or in the form of emulsions. Catalysts to facilitate the proofing process include butyl titanate. The general method of application is to pad fabric with a solution or dispersion of the product and a catalyst, squeeze, dry and then bake at 120-160°C.
- **Fluorochemical finishes** are mainly self-crosslinking cationic acrylate polymers containing a perfluorinated acrylate as the major component. They are applied at around 0.15 - 0.3% o.w.f. as aqueous emulsions by, lick roll or nip padding or vacuum extraction. After drying at 110 - 130°C fabric is baked at 150 – 170°C for 30 – 45 seconds to cure the polymer mixture. **These are superceding the other types of finishes.**

The Padding Process

APPLYING TEFLON® STAIN PROTECTION



The padding method offers high wet pick up, thorough wetting, and complete coverage.
Typical curing conditions are 300-330°F for 1-2 minutes.

DUPONT®

The miracles of science™

Teflon® stain protection DUPONT

Repellant finishes

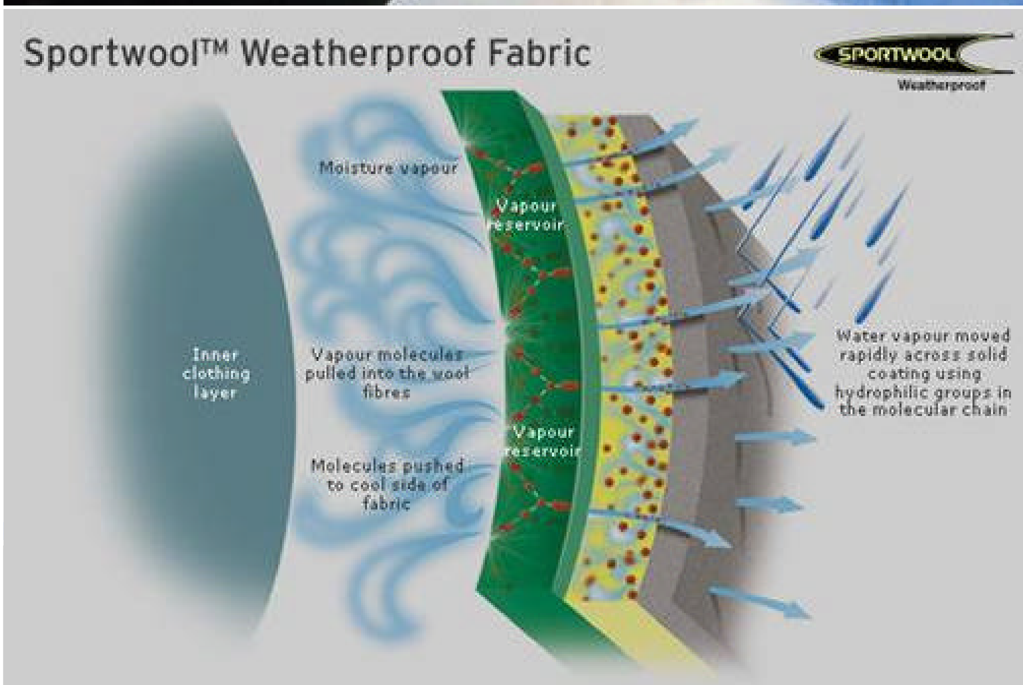
Summary of advantages and disadvantages

Type	Advantages	Disadvantages
Parafin waxes	Good water repellency Cheap	Not breathable Not oil repellent Poor fastness Poor handle
Silicones	Good water repellency Soft handle	Not oil repellent Not soil repellent
Fluorocarbons	Good oil, water and soil repellency Good washing fastness	Expensive

Fluorochemical finishes

- Fluorochemical finishes impart resistance to water and oily-based stains by lowering the surface energy of textile fibres.
- These finishes are extensively used for corporate apparel and upholstery fabrics that are difficult to wash.
- They can have good durability and facilitate soil release during laundering and dry-cleaning.
- Products include:
  - Teflon
  - Zepel
  - Scotchgard.

Multilayer fabric - Sportwool



- The damp, clammy build-up of moisture inside waterproof and windproof garments is removed by 'feeding it' away through the waterproof and windproof layer.
- The inner layer is composed of wool and the outer layer is microfibre easy-care synthetic fabric with an optional outer polymer membrane.
- This is another approach to waterproofing.

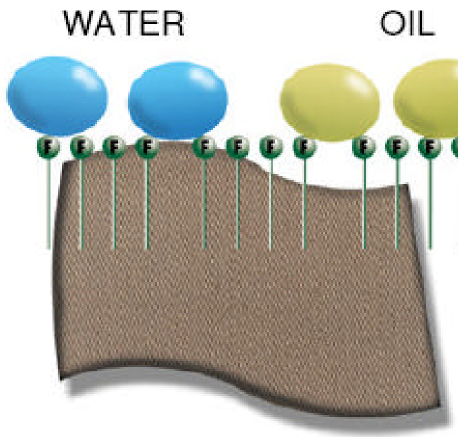
Stain-resist treatments

- Designed to stop staining of wool and nylon carpets by anionic dyes such as are present in wine and artificially coloured foods.
- Are based on treatments to produce high concentrations of negative charges on the fibre surface to prevent adsorption of anionic substances.
- Colourless “dyes” are applied at the end of dyeing processes so that they penetrate the fibres to only a limited degree.
- Blocking chemicals are anionic condensates of formaldehyde with phenolsulphonic acids, naptholsulphonic acids (syntans) and dihydrophenylsulphone.
- A recent development from 3M and Wools of NZ involves co-application of a cationic fluorochemical and a sulphonated phenolic compound. This treatment combines stain blocking with water and oil repellancy.

Fluorochemicals

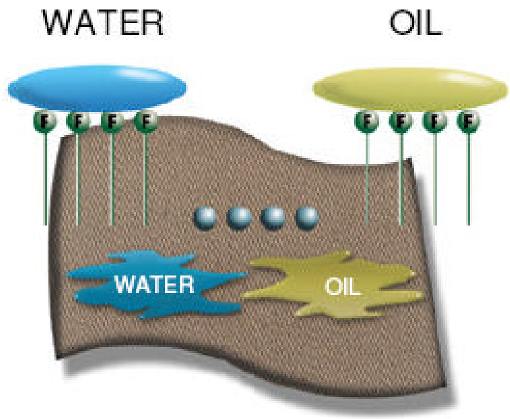
THE CHEMICAL STRUCTURE OF STAIN PROTECTION

Stain Repellency



The fluorinated finish renders the fabric water- and oil-repellent

Stain Release



The fluorinated finish with the addition of water-loving component allows absorbed stains to wash out

DUPONT

The miracles of science™

Teflon® stain protection

Sanitising

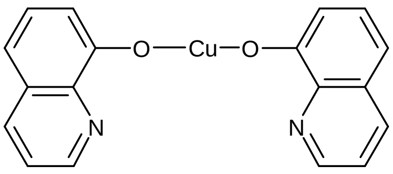
- Hygiene is an important issue with some types of apparel products such as socks and underwear.
- Microbicidal finishes may be used on textiles for the following reasons:
  - to prevent the spread of infectious germs
  - to prevent formation of odours due to bacterial and fungal growth.
- Examples of the organisms and the effects they can cause are:
  - Staphylococcus aureus, a bacterium causing boils and abscesses
  - Trichoptiylon menagrophytes, a bacillus which causes spots and boils
  - Candida albicans, a yeast-like mould which causes thrush and athlete's foot.
- Microbiocidal finishes are important for textiles which are handled continuously by a large number of people. These include mattresses, blankets, pillows, carpets and upholstery used in hotels, hospitals, asylums and student hostels.

Microbiocides

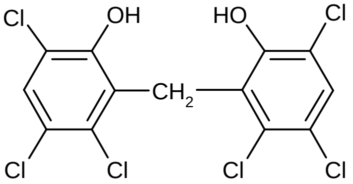
- Microbiocidal compounds are chemicals which kill germs and fungi on surfaces outside the human body. These compounds need to have low toxicity and need to be reasonably well tolerated in the human environment.

Some important microbiocides

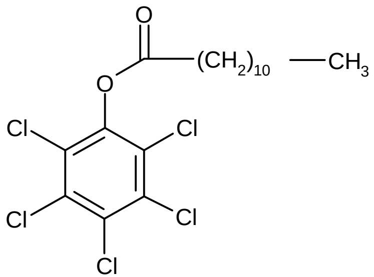
Typical products are: Actifresh (British Sanitised), Antimucin (Sandoz), Fungicide G (Ciba-Geigy), Microcide (Protex), Movin (Bayer), “Bio Guard” (Komatsu Seiren) and Ultra-Fresh (Thomson Research Associates).



Copper 8-hydroxyquinolate



Hexachlorophene



Pentachlorophenly laurate

$Zn[CS_2N(CH_3)_2]_2$

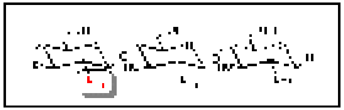
Zinc dimethyldithiocarbamate

- These products can all be applied by exhaustion, spraying or continuous methods.
- Typical application levels are 1 - 4% w/w.
- Re-application during use may be required because many of these finishes are not fast to laundering.

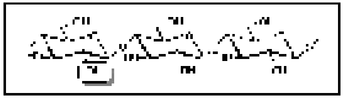
Other approaches to sanitised products

- Chitosan can be applied to textile products.
- Although consumers may wish for perfect hygiene, it is obvious that chemical substances on a textile with germicidal effect may also detrimentally influence the natural flora on the human skin.
- It may be prudent to use naturally occurring mild biocydes on textiles intended for next to skin wear.
- Chitosan is a biopolymer produced from Chitin and it has a similar structure to cellulose.
- Chitosan has a bacteria-impeding effect and can be used for the antibacterial finishing of textiles.

PERICID B



chitosan

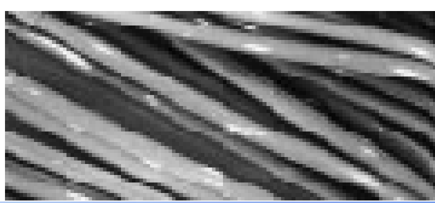


cellulose

- Chitin is a raw material which is growing in an enormous amount
- Chitosan produced from chitin shows some interesting properties:
  - antibacterial and fungizide effect, wundheilend
  - biologically degradable
  - not toxic
  - film forming when drying
  - wash resistant

Antibacterial fibres

- Special textile fibres with intrinsic anti-bacterial properties are now being made. One example is ‘Chitopoly’ developed by the Fuji Spinning Co., Ltd.
- This is a polynosic type of rayon containing a dispersion of chitosan. The fibres are biodegradable.
- The effectiveness of the fibres is not decreased by washing.
- Chitopoly is usually blended with cotton to make underwear, night wear, socks, towels, handkerchiefs, mats, sheets and stuffed toys.
- This is an example of the way in which high-performance fibres are now being engineered for specific purposes. This type of approach to product development has potential to replace the add-on technologies which have long been the basis of much functional finishing.



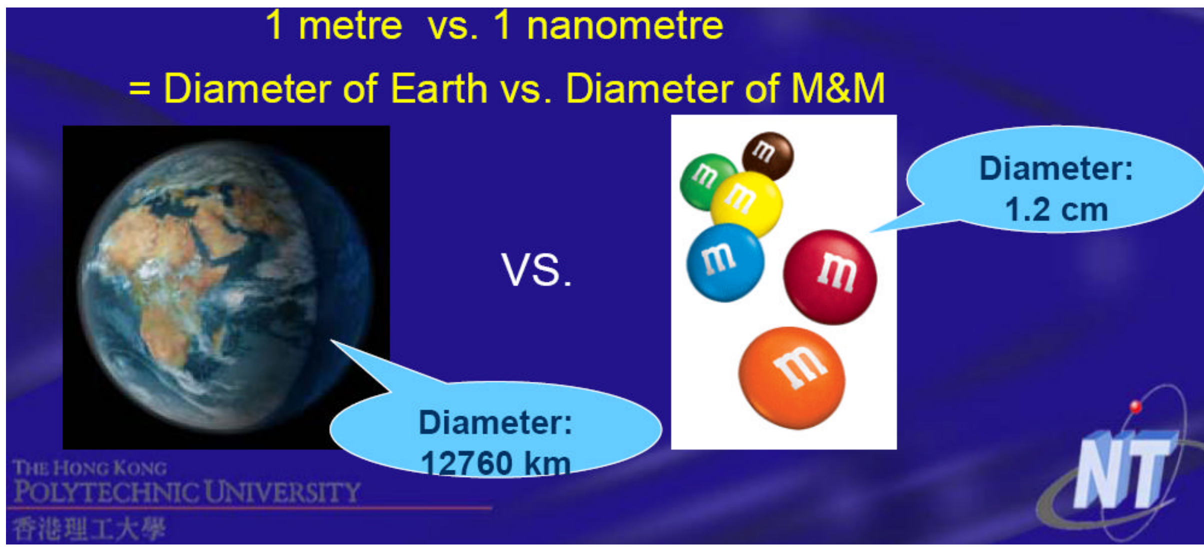
The white areas are chitosan.

For Sensitive Skin

CHITOPOLY

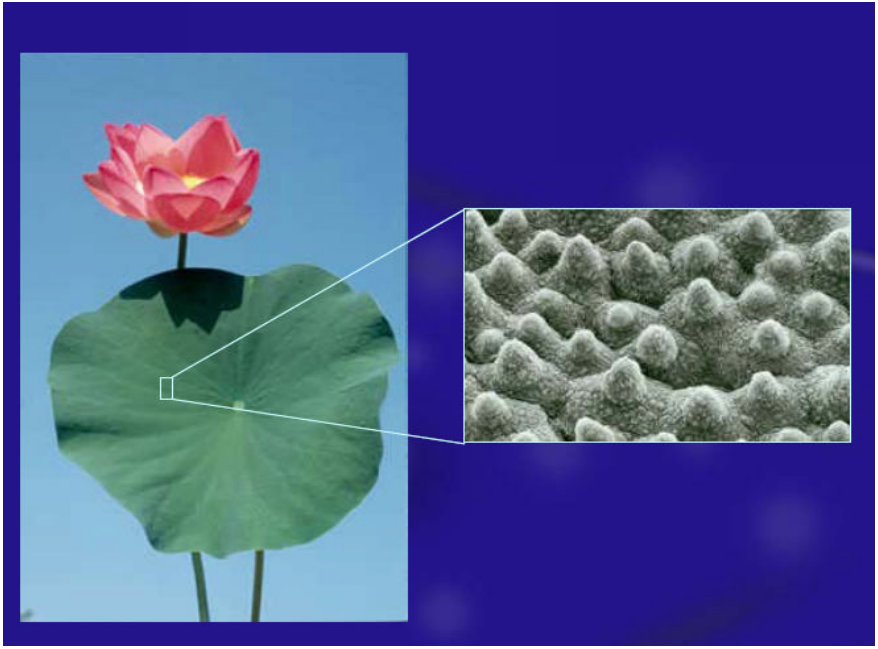
Nano-finishes

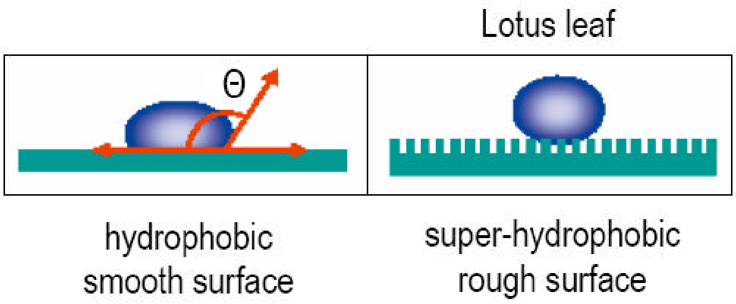
- These can be defined as methods of changing properties of textile goods by application of very small particles of finishing agents or by modification of very thin layers on the surfaces of textiles.
- Nano = 10-9m



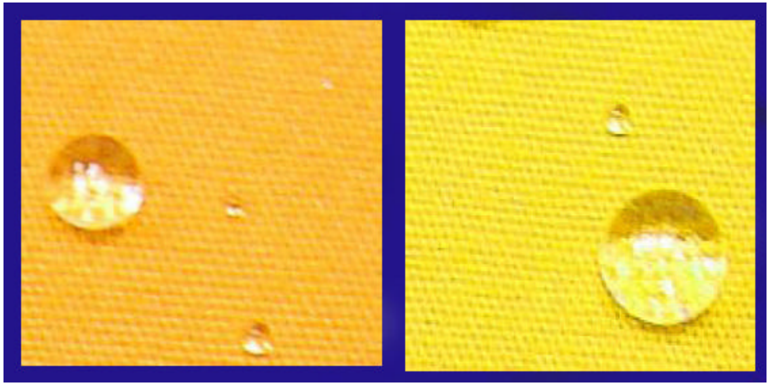
The lotus leaf effect

Waterproofing with nanoparticles.





Textiles treated with TiO_2 nanoparticles



Treatment of textiles with nanoparticles

- Anchoring of nanoparticles onto fabrics is achieved by using acrylic and polyurethane binders applied by impregnation-dry methods.

- The enemies of nanofinishes are aggregation of the particles and smothering of the particles with polymers intended to bind them to the surfaces of textile fibres. The best effects are usually generated with small quantities of nanoparticles.

Inorganic nanoparticle systems

- The particles consist of many metal oxides whose chemical and physical characteristics make them useful for special finishes for the textile industry.
- TiO_2 is the most well-known. However, particles containing silicon and aluminium can be found in many forms (silicates, aluminates, oxides etc.) provide useful properties.
- Nanoparticles (10^{-9} m) are obtained by sol-gel synthesis in water or organic solvents.
- Nanoparticles posses a high surface area to weight ratio and this gives them some considerably enhanced properties.

Enhanced functionalisation of fabric using nanoparticles.

UV Protection

- metal oxides,TiO_2 in colloidal form

Hydrophobicity

- water and oil repellence: TiO_2

Thermal comfort

- ceramic particles, montmorillonite

Flame retardant

- montmorillonite and ZrO_2

Antibacterial, fungicidal

- $BaTiO_3$ or silver compounds

Electrical conducibility

- aluminum, silver and other metal derivates in combination with polypyrrole

Pilling resistance

- montmorillonite, carbides and ZrO_2

Mechanical resistance

- carbides, ZrO_2, silica, other metal oxides

A nanoparticle product

SoleFresh™
Nano-silver Socks
Click to purchase now

SoleFreshT contains 0.3% w/w nano-silver

- Eliminates foot odour
- Prevents Athlete's Foot
- Prevent foot infection in patients with diabetes
- Keeps feet dry and fresh

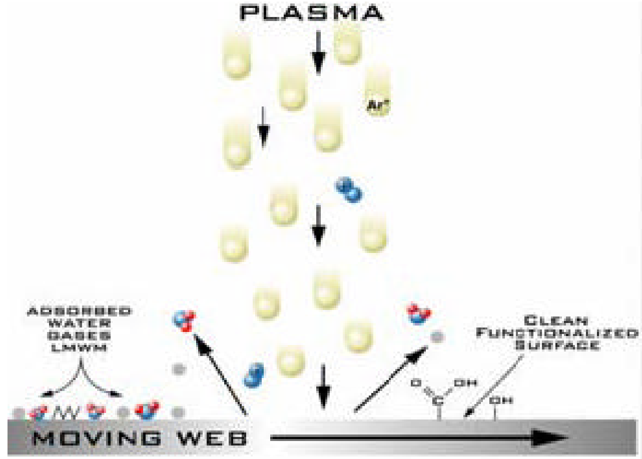
Colour Black only

- 80% Cotton
- 20% Elastic yarn

Plasma treatments

- A plasma may be described as a mixture of electrons, ions and free radicals and is produced from an electrical discharge, either under vacuum or atmospheric pressure.
- Plasma treatments are applied to increase the wettability (surface energy) of a substrate and, in doing so, promote adhesion with whatever is subsequently applied.
- The effect of a plasma treatment on wool enhances the wettability of the fibre, which has implications for improved dyeing, printing and the subsequent application of a variety of different chemical treatments.
- Plasma treatments represent probably the most elegant approach to fibre modification for shrink-resist effects because they are surface specific, effluent free and thus environmentally friendly but they have still to be commercially proven.

Atmospheric plasma treatments

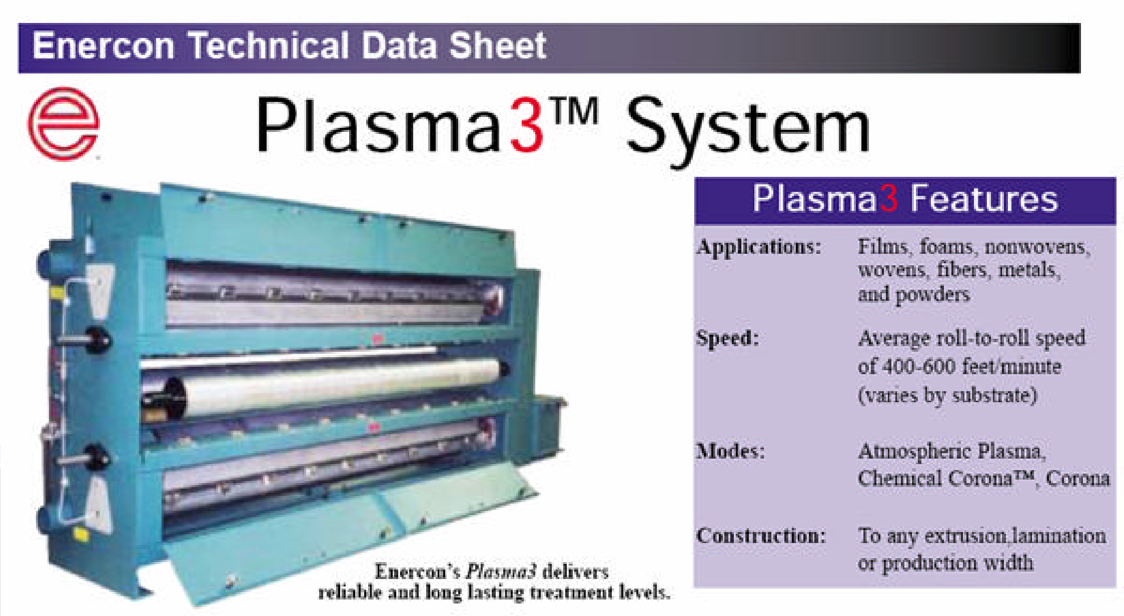


Sigma Technologies

- Atmospheric plasmas can be created using argon or helium as carrier gases.
- In a high frequency electric field, the carrier gas becomes excited and the resulting plasma contains ions, free radicals, electrons, neutral species, and photons, but the temperature remains low.
- Reactive species in the plasma may modify the surface of fibres, fabrics or films.

Nanolayer finishing technology

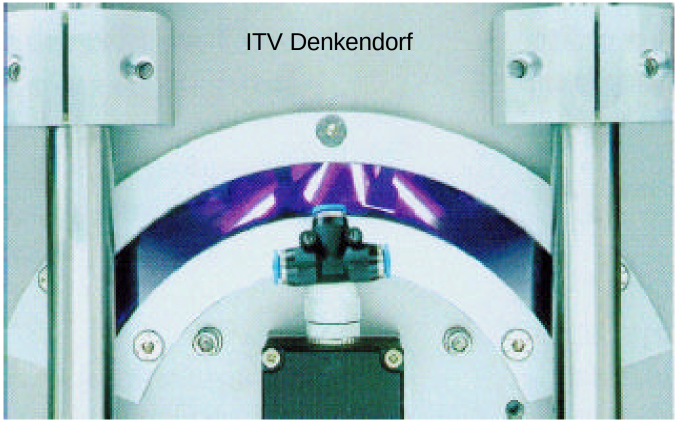
- Corona and vacuum plasma treatment machines for modifying fabric surfaces have been available since the 1970s.
- Commercial plasma treatment at atmospheric pressure has only become available in the last few years.
- Atmospheric plasma machines are cheaper, easier to use and more productive.



Uses of plasma treatments

Additional Gas	Result	Effect on Surface
Oxygen	Oxidation	More hydrophillic Easier to print Better adhesion of polymers Cleaner Sterilised
Hydrogen	Reduction	More hydrophobic
Tetrafluoromethane	Fluorination	More oleophobic and hydrophobic

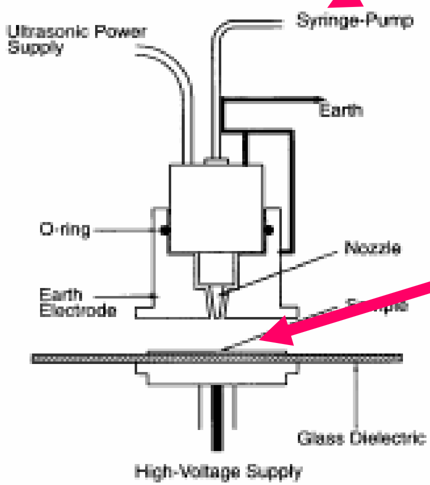
- Some treatments may last only for several hours.
- Treatments may be easily abraded away because the treated layer can be very thin.
- More permanent treatments are obtained by plasma grafting.



Plasma grafting

Well controlled coatings chemistry – at Atmospheric Pressure

- Liquid precursor is introduced directly into the APGD via an ultrasonic nebuliser.
- Laboratory scale enabling wide range of liquid precursors, developed at University of Durham.
- Demonstrated high retention of precursor chemistry
- Dow Corning Patent WO02/28548.



Dow Corning Plasma Solutions

April 2003

Treatment chemicals for functional finishes (e.g. dissolved polymers) are sprayed directly into the atmospheric plasma, using an ultrasonic nebuliser.

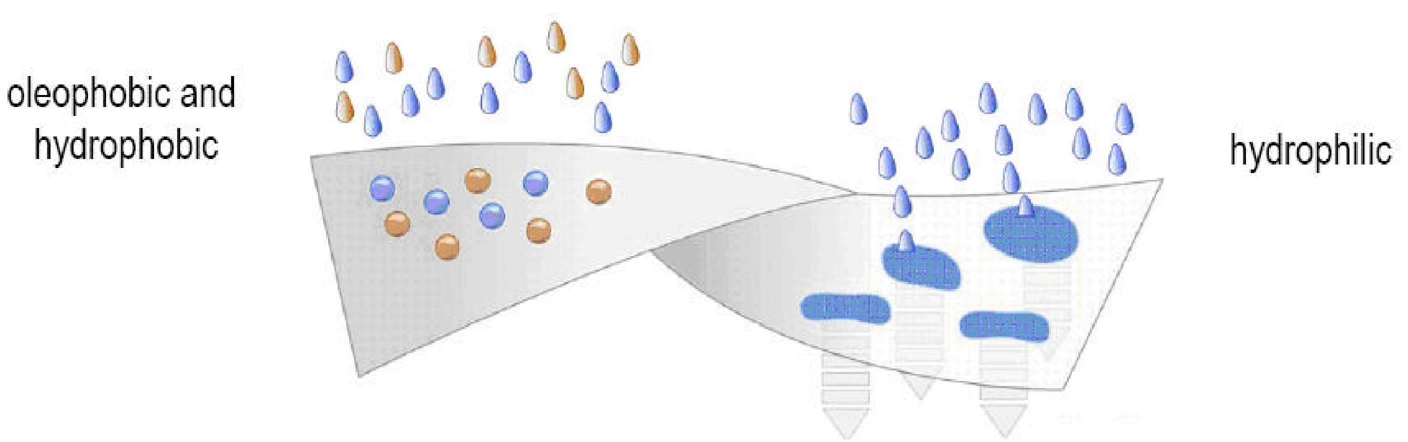
Reactive species generated in the plasma are deposited on the material to be treated and react to form a coating up to several microns thick.

Coatings may be post cured by heat, UV etc.

In the future, this technology could change the way in which functional finishes are added to textile products.

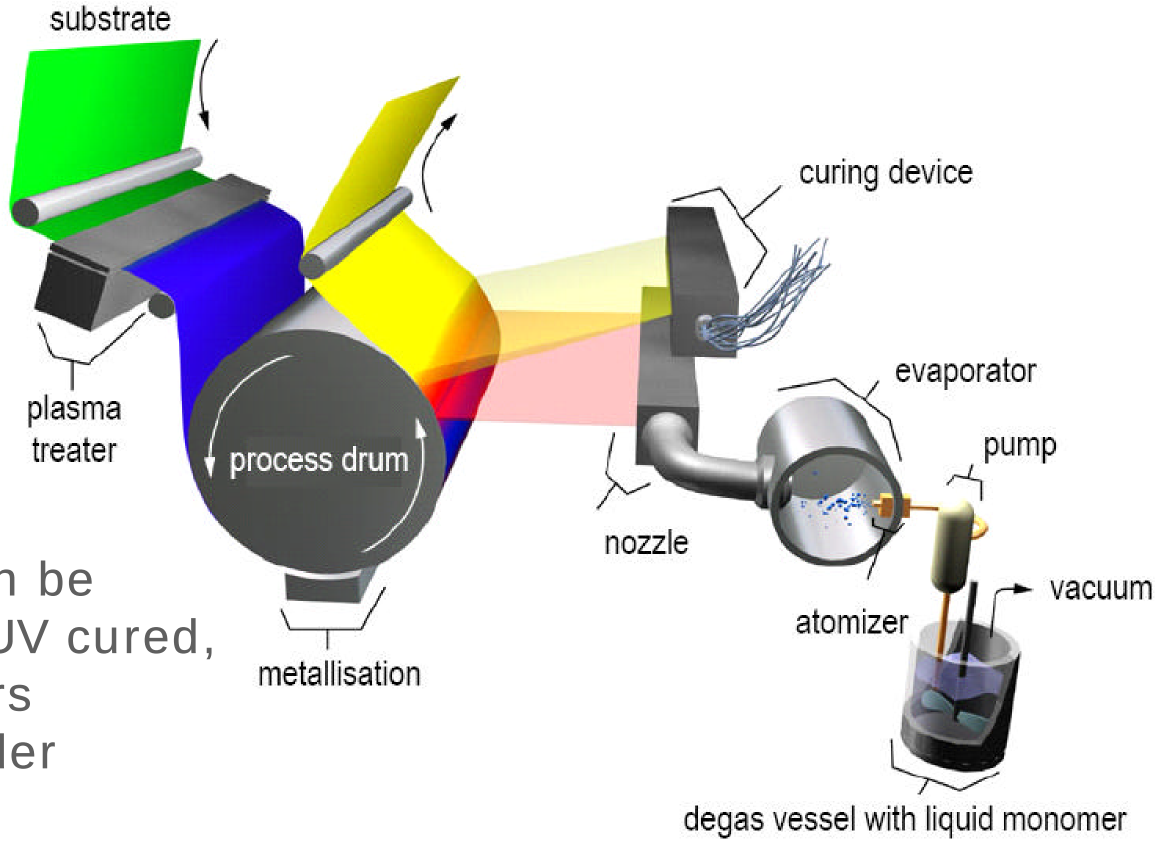
Nanocoating

Achieved by treatment with plasma without and with special chemicals what can be activated in the plasma.



Different functionalities can be obtained on opposite sides of a fabric

DryFab nanolayer coating



Monomers can be applied, and UV cured, or metal layers deposited under vacuum.

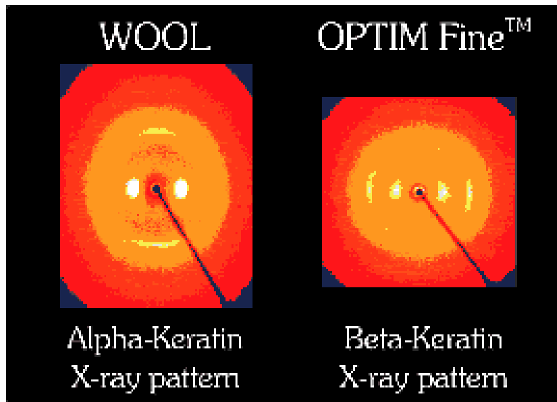
Making wool fibres thinner

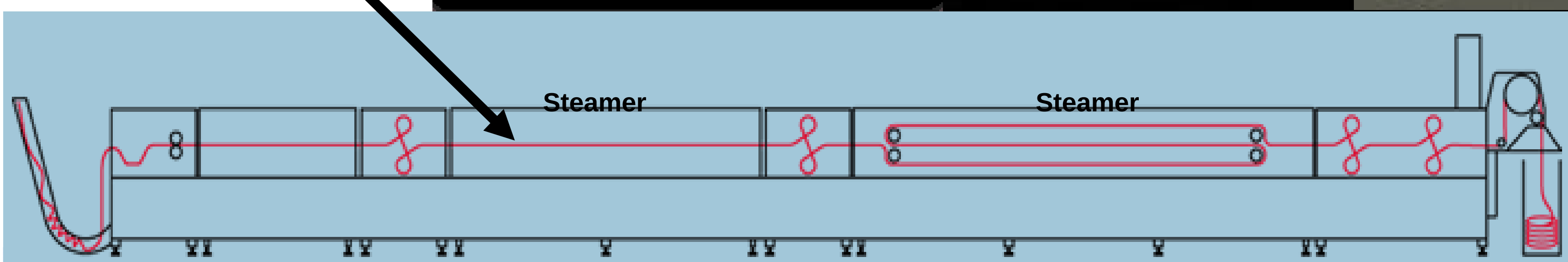
OPTIM™

SUPREME LUXURY FIBRES

X-ray diffraction shows that the wool has been changed from a to ß keratin

This fibre is made by chemical treatment followed by physical stretching of wool fibres and finally stabilising them in the stretched form.

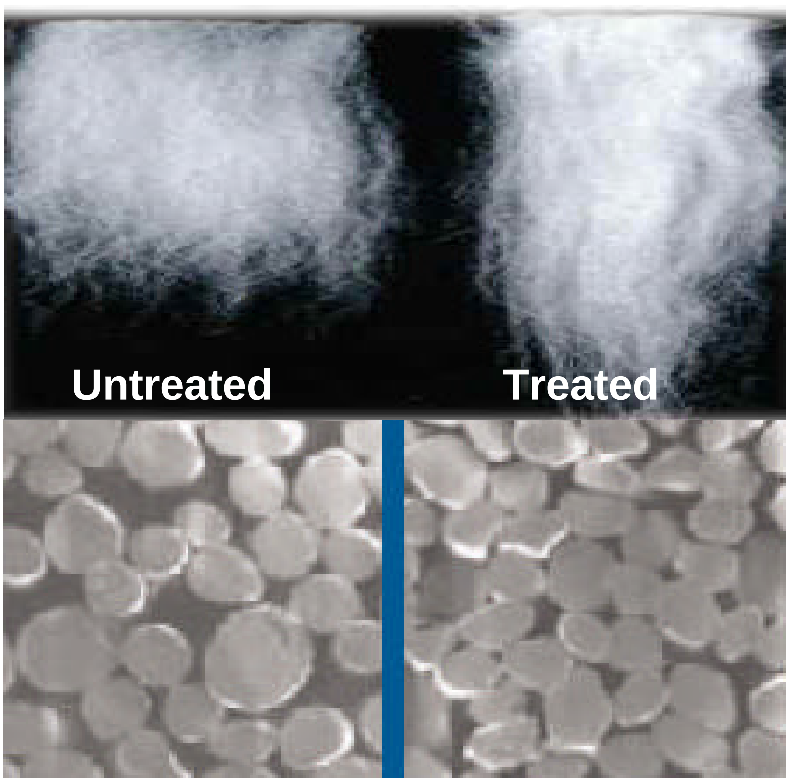




Optim Fine fibre

OPTIM™ Fine fibre treatment gives wool a silk-like quality for extremely fine, soft and light-weight fabrics.

There is a 3 micron reduction in the mean fibre diameter.



Optim can be made finer than the finest natural wool fibres.

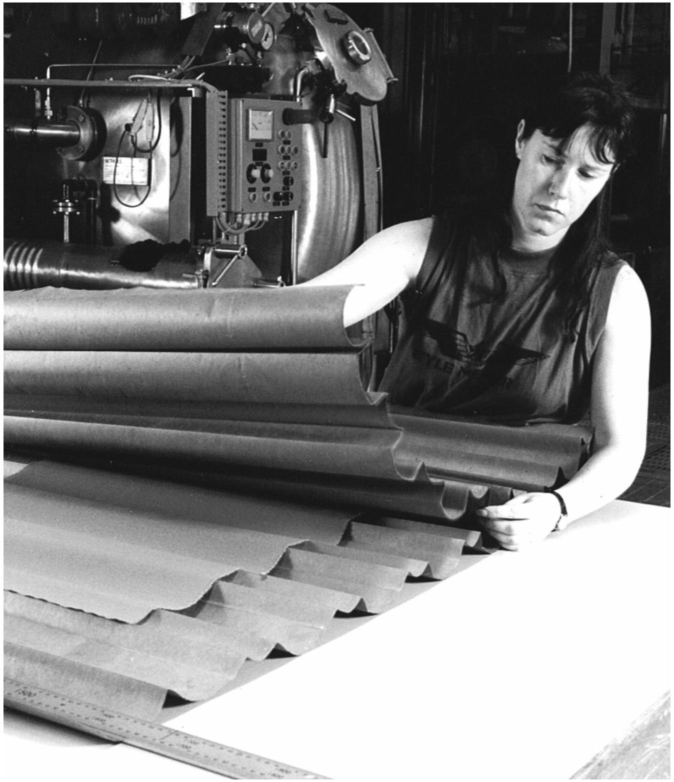
Garment setting

There are a number of processes that can be used on garments to permanently set creases and seams.

- paper pleating
- Siroset
- Lintrak.

Pleating

- Pleated panels manufactured from wool fabrics are normally permanently set before the garment is finally made up.
- The panels can be treated by the Siroset process or by pressure steaming.
- In the steam setting process, the fabric panels are pleated by interleaving them between pre-formed sheets of treated cardboard, normally called ‘papers’.
- The papers are rolled into a package and the package is then steamed in an autoclave at 110^{o}C for 10 to 30 minutes.



Pleating

Fabrics to be pleated require careful finishing. For optimum appearance of pleats a small amount of relaxation shrinkage (RS) must be introduced (depending on the fabric weight (W)) to offset the hygral expansion (HE) of the fabric.

$$RS = (0.4 \times HE) - (0.01 \times W) + 2.0$$

Weight / unit area (g/m^2)	HE = 4%	HE = 6%
150	2.0	3.0
200	1.5	2.5
250	1.0	2.0
300	0.5	1.5

Pleating

Fabric type	Warp stenter setting	Weft stenter setting	Dry finish tension
Plain weave, piece-dyed	'Zero' overfeed	7-10 cm over wet width	High warp tension
Steep twill, piece-dyed	'Zero' overfeed	5-7 cm over wet width	High warp tension
Colour-woven	'Zero' overfeed	5-7 cm over wet width	Normal warp tension

- The settings aim to produce zero extension in the warp direction during stentering.
- In practice, 'zero' overfeed usually results in some underfeed on the fabric, due to inadvertent stretching.
- Attempting to introduce relaxation shrinkage in both directions on the stenter, with warp underfeed as well as width tension, may lead to skewness in the fabric.
- Warp relaxation shrinkage can be introduced later by applying warp tension to the fabric when it is loaded into a semi-decatiser.
- However these suggestions are only semi-quantitative.

Permanent creasing of wool

- A permanent creasing or pleating method for wool garments is known by the trade name of SIROSET and was developed and patented by CSIRO.
- It consists of treating by spraying the area of a garment to be creased or pleated with a reducing agent, (e.g. ammonium thioglycollate or monoethanolamine sulphite (MEAS) or cystiene), and then setting the creases or pleats by means of steam pressing, or less comonly in an autoclave.

Siroset

- This process is used to set permanent creases in wool fabrics – mainly skirts and men's trousers.
- The Siroset Processors Association in Japan announced that annual processing volume of Siroset permanent crease treatment in 2000 reached 4 million pairs of men's pure wool trousers of which 2.4 million pairs were treated in 29 mills in China, Thailand, the Philippines and Vietnam.

Without and with Siroset.

The Siroset process

- The Siroset process, as used in Japan, is quite simple.
- For men's trousers, a setting agent is sprayed onto the trouser, especially on the creased parts, steam press for 70 seconds and then dry.
- The setting agent used is cysteine, called TYCS, abstracted from human hair.

LINTRAK

- This method of stabilising creases was developed in collaboration with the International Wool Secretariat (The Wool Bureau in the USA).
- The LINTRAK system can be used on majority of fabric types, both man-made and natural.
- A bead of silicone resin is applied in the inside of the creases of slacks and shirts. The resin holds the crease closed.
- Once the resin has been applied, no further pressing or heating is required.
- LINTRAK can also be used to hold creases closed during permanent setting operations for wool, such as pressure steaming.
- A major end-use is for uniforms.

Problems with static electricity

- Static charges build up whenever dissimilar materials which are poor conductors of electricity are rubbed together. A separation of charges occurs and one of the materials becomes positively charged and the other negatively charged.
- High voltages can be generated which are discharged with unpleasant, and sometimes dangerous, results - electric shocks or ignition of inflammable materials.
- Static electricity problems are often encountered in mills, particularly with dry fabric after drying.

Antistatic finishes

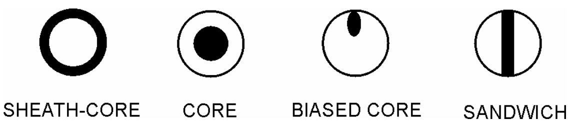
- Static electricity gives relatively little trouble with the natural fibres and can be readily regulated by controlling humidity to a reasonable level so that the regain moisture provides the fibres with sufficient conductivity to dissipate any charge.
- Problems are sometimes encountered with wool, particularly carpets, when it is warm and the relative humidity is low.
- Antistatic treatments make the textile fibres conductive so that high charge densities are dissipated before sparks can fly.
- This is done by the application of anionic or cationic agents to the fibre but the treatments are not very effective.

Antistatic fibres

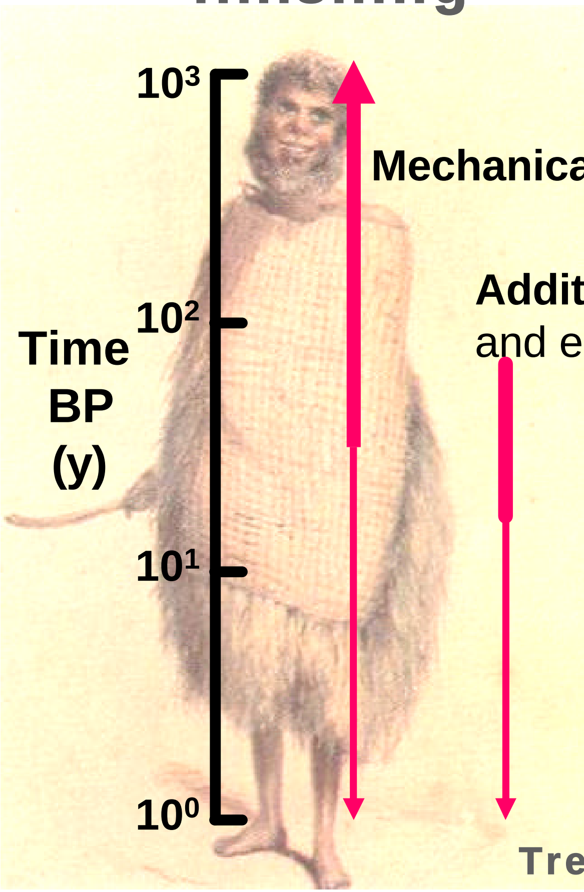
- Fine metal wires have been used in carpets, particularly in the backing, to conduct charges away.
- Recently, conductive fibres have been developed and these may be blended with other textile fibres to dissipate charges.
- Early fibres were black and therefore are unsuitable in some situations but Kanebo Gohsen Ltd. has recently released a newly developed sheath-core types of electro-conductive fibre - Belltron.
- Anti-static fibres may be used in dust-free garments, work wear, sweaters, formal dresses, carpets and upholstery, car seats, blankets and curtains as well as industrial uses such as air filters, brushes and transmission belts.

Belltron conductive fibre

- This is a **bicomponent fiber** that **combines matrix polymers** (nylon or polyester) and **electro-conductive particles** (carbon or a white metal compound).
- A small amount of Belltron is **blended** with other types of fibres.
- Because the conductive particles are encapsulated, the conductive effect has **high durability** to washing, flexing and abrasion.
- The product is available in black and **colours**.
- Cross sections of Belltron fibres include the sandwich type in which carbon particles are sandwiched between the matrix polymer; as well as the sheath-core types in which a white metal compound core is sheathed in coloured matrix polymer.



Summary of developments in textile finishing



Mechanical action (beetling, milling, pressing, raising etc.)

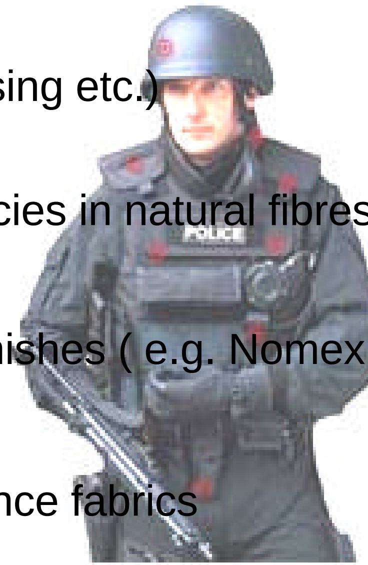
Additive finishes used to overcome deficiencies in natural fibres and early synthetics

Special fibres replace additive finishes (e.g. Nomex, Kevlar, Spandex)

Multilayer, high performance fabrics

Intelligent fabrics

Nanolayer technologies



Trend: Technology is increasingly sophisticated.

The future

- For textiles in general, functional finishes for highly specialised end-uses will be replaced by specially engineered fabrics (multi-layered when necessary) made from synthetic fibres with special chemistry.
- With natural fibres such as wool, with limited scope for chemical modification, functional finishes will remain important but the effects may not be as spectacular as can be obtained with fully synthetic products.