

# Innovation in the colouration of wool

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Deakin University

# Colouration is subject to general trends within the textile industry

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- Many current and future innovations will be determined by economic factors that have become well established during recent times.
- The major requirements are to:
  - reduce processing costs
  - introduce new profitable products and processes.

# Innovations topics

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1. Processing
2. Dyes for wool
3. Dyeing machinery
4. Dyeing methods to protect the fibre
5. Dyeing modified wool fibres
6. Bleaching wool
7. Improving the light-fastness of dyeings
8. Digital printing technology
9. The future

# 1. Innovations in processing

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# Current and future changes in dyeing

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- Coloration is moving to later stages in the processing sequence.
- Loose stock and top dyeing are becoming less important.
- Yarn, piece and garment coloration are increasing.
- Just-in-time processing.
- Right first time.

# Requirements for colouration processes

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As colouration moves to later stages in production, there is less leeway for error.

This demands sophisticated and robust production technologies:

- automatically controlled, highly efficient, dyeing machines
- automatic dispensing equipment for dyes and chemicals
- a range of sensors that can be used to monitor the operation of dyeing machines
- improved dyes and associated dyeing methods
- reliable methods for preparation of goods before dyeing.

# Automation

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- Automation is now well established in the dyeing industry and robotics are being introduced at an ever-increasing rate.
- Blind dyeing techniques have been practised now for many years.
- The robotised, 'lights out' dye house operated with the minimum of staff is becoming more common.
- A 'lights out' operation is likely to be run by mechanical and electronics engineers and not dyers in the conventional sense.

# Automation of loose stock and top dyeing

OBEM SpA's technology focuses on dyeing systems created in modular form that facilitate flexibility and versatility by modifying lot size.

Flexibility is evident in the design of a four-unit, 250-kilogram-per-unit machine that can run in a 1000-kg mode or a 250-kg mode, allowing the textile manufacturer to adapt to business conditions.





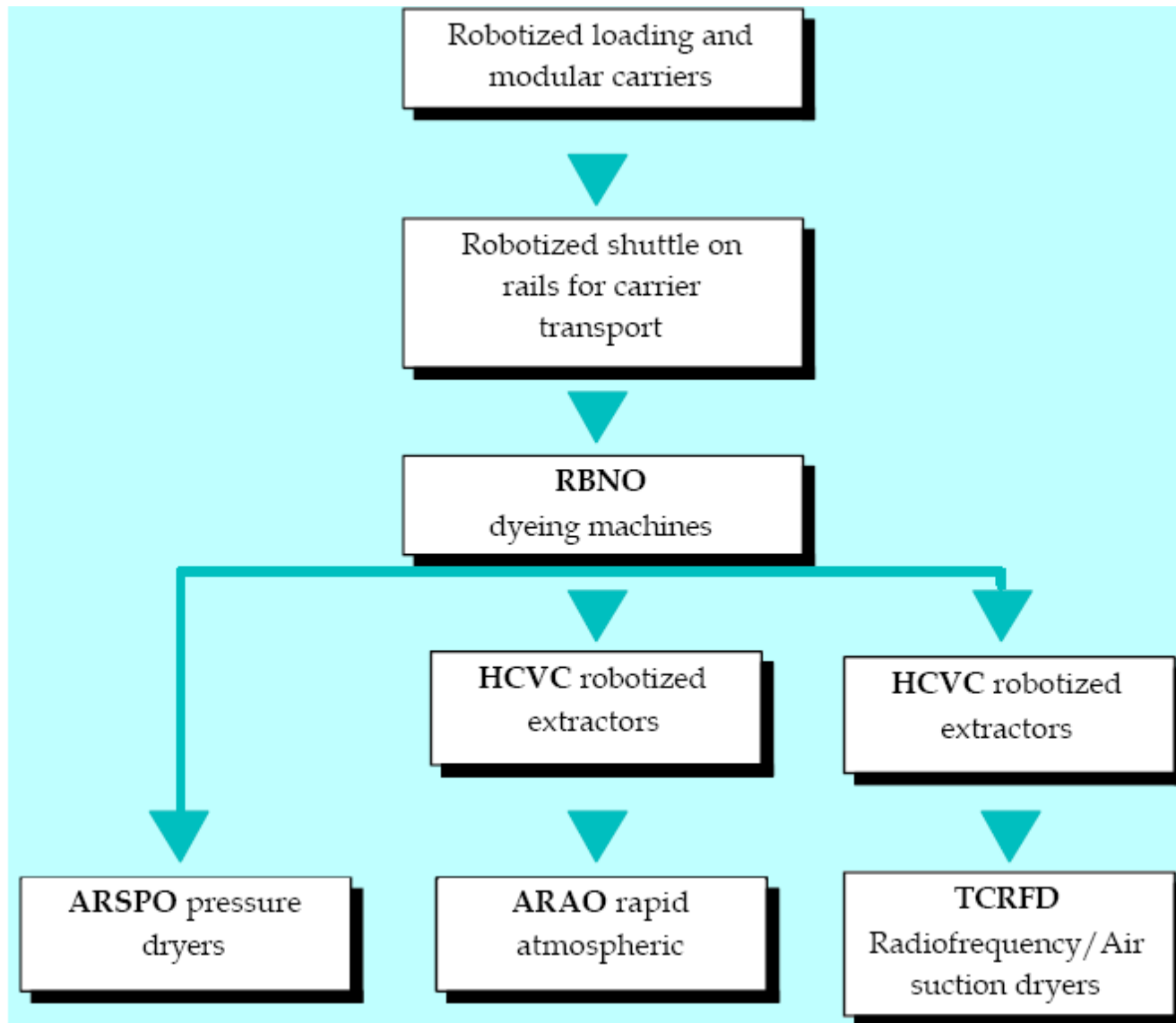
# OBEM automated hank dyeing



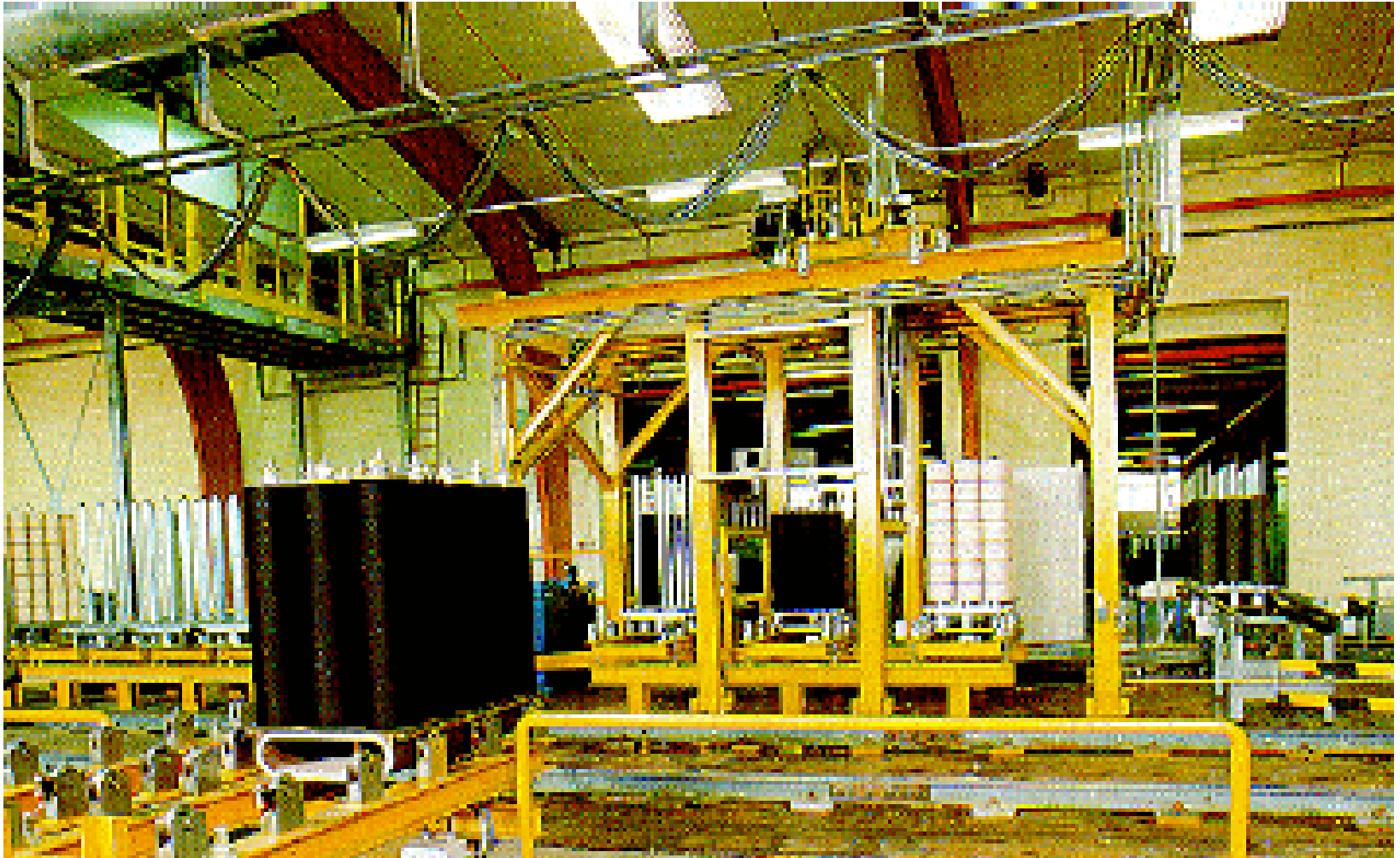
- The company's latest technology is the TMB/SV-TR, fully robotised hank-dyeing system.
- The machines use a specially designed spray hank arm. The hanks are processed without tension. The system is particularly suited for fine and soft yarns.



# RBNO robot package dyeing plant



# RBNO robot package dyeing plant



Packages are loaded on dyeing spindles and compressed.



# RBNO robot package dyeing plant



Packages are transported to the dyeing machines.

# OBEM robot package dyehouse



- The robotisation of the dye house is the consequence of continuous research aimed at the development of more reliable systems.
- Here you can see some robotisation solutions for package dyeing.





# OBEM dyeing machinery robotisation software

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- This software controls all robotised units in the dyeing plant, including shuttles, overhead cranes and loading and unloading of the automatic dyeing machines.
- The software is called VisualDye Handling. It runs on a PC normally located in the office.
- Through appropriate interfaces the robotised plant is monitored and its operation recorded in real time, including the actual position of the shuttle and the type of material loaded in every dyeing machine, press, centrifuge, dryer and storage area.
- Direct instructions can be sent to the shuttle, and priorities in operation of the machines can be changed.



# Benefits from dyehouse automation

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- Programmable process control (by microprocessors) results in 10-30% saving in water and energy use 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 results in 10-15% savings in dyes, pigments and chemicals.
- Lower discharges with less pollution and lower cost of effluent treatment.
- The costs of automation are 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.

## 2. Innovations in dyes for wool

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# New trends

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- Systems approach to dyeing.
- Granular and liquid forms of dyes and chemicals suitable for automatic dispensing.
- Reduction in inventory of dyes.
- Eco-labels -
  - metal-free dyes.

# Systems approach to wool dyeing

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- Today, the emphasis is no longer on the chemistry or structure of dyes but their functionality and compatibility.
- Dyes are not necessarily grouped according to chemical type, i.e. acid, milling, premetallised, reactive.
- Colourants are made up of mixtures of dyes to give desired dyeing behaviour and fastness properties and to meet specific ecological requirements.

# Lanaset (Ciba) and Supralan (DyStar) dyes - the systems approach to wool dyeing

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- These dyes include two entirely different classes of dye. Some are fibre reactive dyes that react with wool; others 1:2 premetallised acid dyes.
- They all attach to wool under similar conditions, and may be intermixed freely.
- The dyes have similar fastness properties.
- It does not matter to the user which of the Lanaset dyes belong in which class.

# Öko-Tex label

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- This is a typical eco-label for textiles.
- It was founded in 1993 by the Austrian Textile Research Institute.
- Interest has grown to such a level that it is now recognised the most important textile eco-label in the world.
- There are 12 institutes all over Europe, together with associate institutes over the world, which can test textile products and award the labels.



# Öko-Tex 100 standard

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The list of potentially harmful substances that the Öko-Tex 100 standard checks for, and places limiting values on in products, are as follows:

- **pH**
- formaldehyde
- **heavy metals (As, Pb, Cd, Cr, Co, Cu, Ni, Hg)**
- pesticides
- **chlorinated phenols**
- **dyestuffs (specific types based on harmful amines)**
- **chlorinated organic carriers**
- biocidal finishes
- flame retardant finishes
- **colour fastness**
- emission of volatiles
- odours.

The categories in bold above can be involved in dyeing.

Labels such as these have led dye manufacturers to group dyes into new ranges that can allow dyed goods to pass the necessary standards.

Wool-polyester blends will need to be dyed with special carriers or above the boil with protective agents for wool.

# Eco-labelling of dyed wool articles

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- Eco-labels have led dye manufacturers to group dyes into new ranges that can allow dyed goods to pass the necessary standards.
- Wool can generally qualify for these labels if chrome and premetallised dyes are replaced by milling and reactive dyes, depending on the end use.
- Wool-polyester blends will need to be dyed with special carriers or above the boil in the presence of special protective agents for wool.

# Dyes with chromophores that do not contain heavy metals

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- These metal-free dyes have fastness characteristics approaching those of dyes that previously contained heavy metal chromophores.
- New reactive dye ranges (e.g. Lanasol CE – Ciba, Realan - DyStar).
- Optimised ranges of metal-free acid dyes (e.g. Sandolan MF – Clariant).
- These achieve a balance of economy and performance comparable with chrome dyes in certain applications, such as piece and hank dyeing, especially bright fashion shades.

# Sandolan MF dyes

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- MF stands for metal free.
- The dyes are of the milling type and are applied at pH 4-6 with minimum damage to the wool.
- The dyes have good compatibility between different members of the range for rate of dyeing and migration.
- The standard trichromatic combination recommended by Sandoz is:
  - Sandolan Golden Yellow MF-RL
  - Sandolan Red MF-2BL
  - Sandolan Blue MF-GL.
- The recommended dyeing method is robust, with:
  - high exhaustion
  - good coverage of tippy wool
  - relative insensitivity to the pH and temperature of application.
- The dyes have good wet fastness suitable for carpets.
- Applicable to wool/nylon blends.



# 3. Innovations in dyeing machinery

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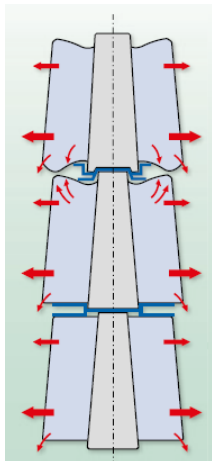
# Innovations in yarn dyeing

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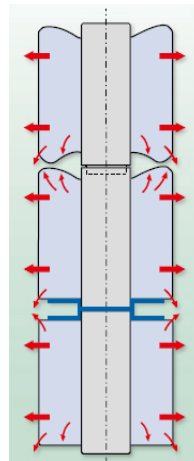
- Many advances have been made in machinery design, package preparation and package drying.
- Wool is able to benefit from most, if not all, of these improved technologies.
- The preferred method for wool is to dye press-pack, parallel sided, precision wound, packages and to dry using radio frequency or rapid hot air dryers.

# Package preparation for yarn dyeing

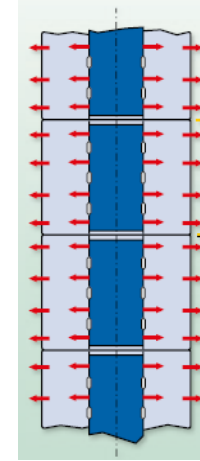
Yarn dyeing requires precision package winding and can be carried out in newer types of robotic machines.



**Cones have uneven flow characteristics.**



**Unpressed parallel-sided packages give poor flow at edges, even with spacers.**



**Compressed parallel-sided packages give the best flow.**



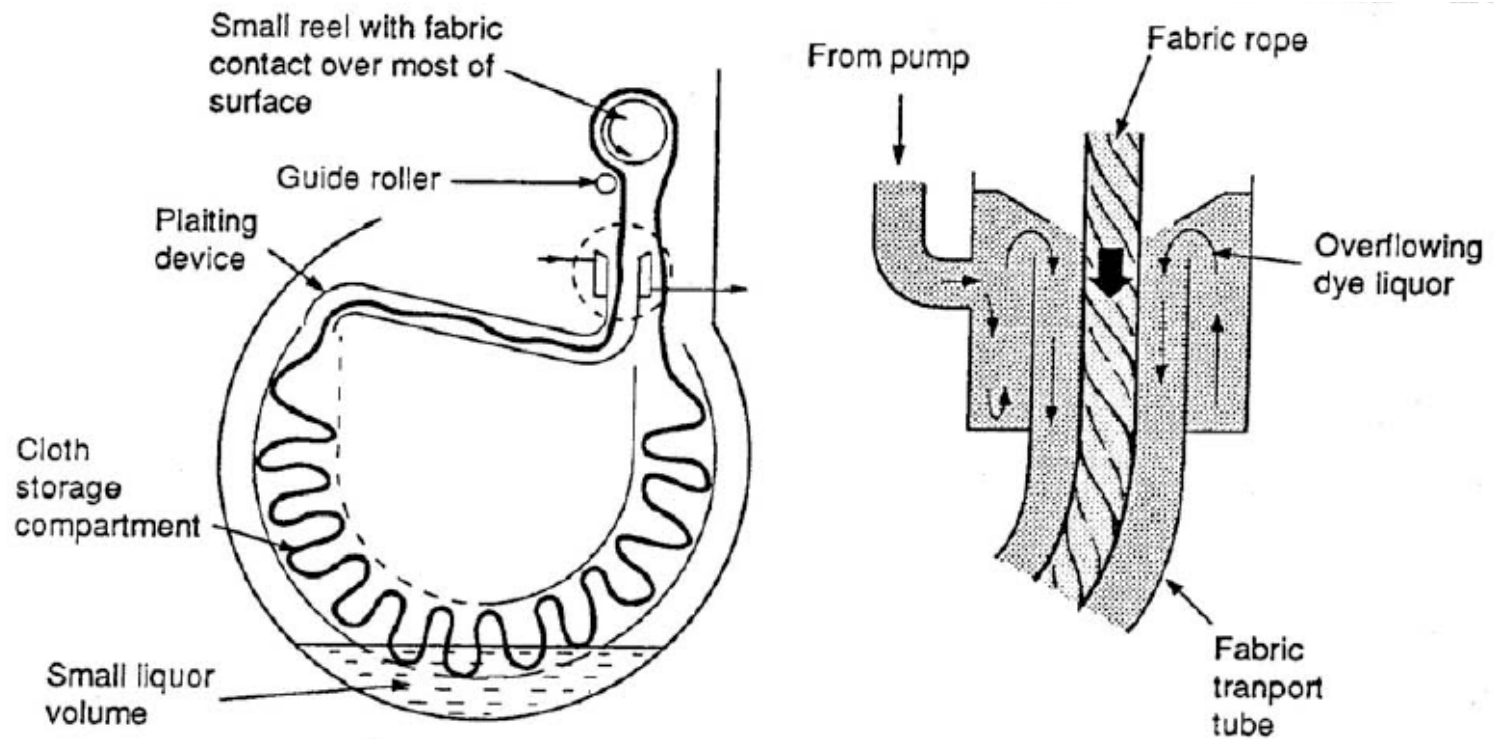
**Zweiter precision package winder for high density parallel-sided packages**

# Wool fabric dyeing

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- The traditional open winch for dyeing wool fabric had many disadvantages:
  - poor circulation,
  - inadequate temperature control,
  - difficulties with rig marks.
- Piece dyeing machinery for wool has piggybacked on developments for jet dyeing of synthetics
- Only certain designs can be used because of the need for gentle handling of wool fabrics.
- Stretching of fabric, vigorous mechanical action and excessive compaction of fabric must be avoided:
  - wool is prone to become felted and is always permanently set while it is being dyed.

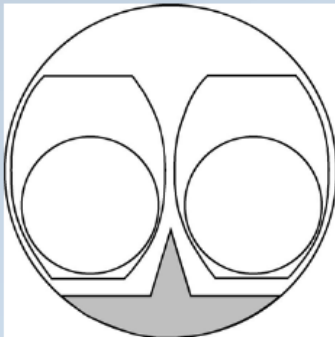
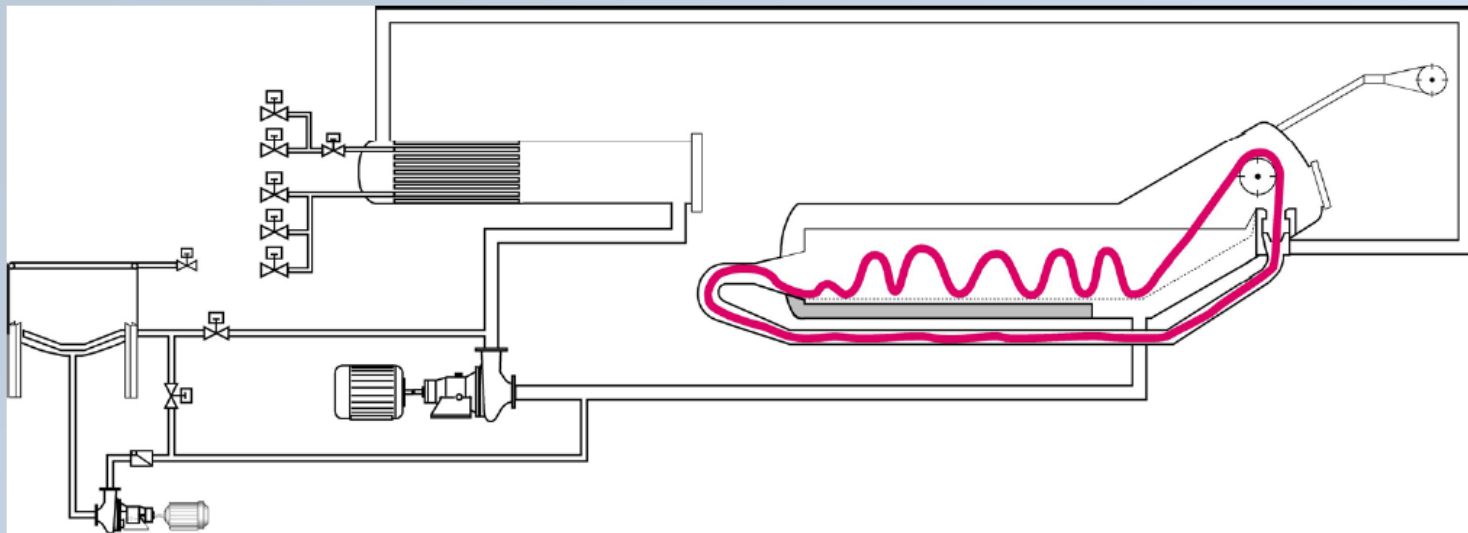
# Overflow jet dyeing machine for wool fabric



**Stretching of fabric, vigorous mechanical action and excessive compaction of fabric must be avoided.**

# A soft flow, low creel, overflow jet dyeing machine for fabric

## soft TRD DS XL



- **new internal chamber design** ⇒ lower liquor ratio
- **compact machine design** ⇒ minimal floor space requirement
- **short fabric circulation and ,flooded‘ fabric transport** ⇒ gentle handle of fabric

# 4. Innovations in dyeing methods to protect the fibre

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# Preserving the quality of wool during dyeing

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- Problem:
  - Unlike many other textile fibres, wool is chemically degraded while it is being dyed. This makes fibres weaker, so processing costs rise and end-product performance deteriorates.
- Solutions:
  - Dye at temperatures below the boil or for a short time at the boil.
  - Use anti-setting dyeing technology.

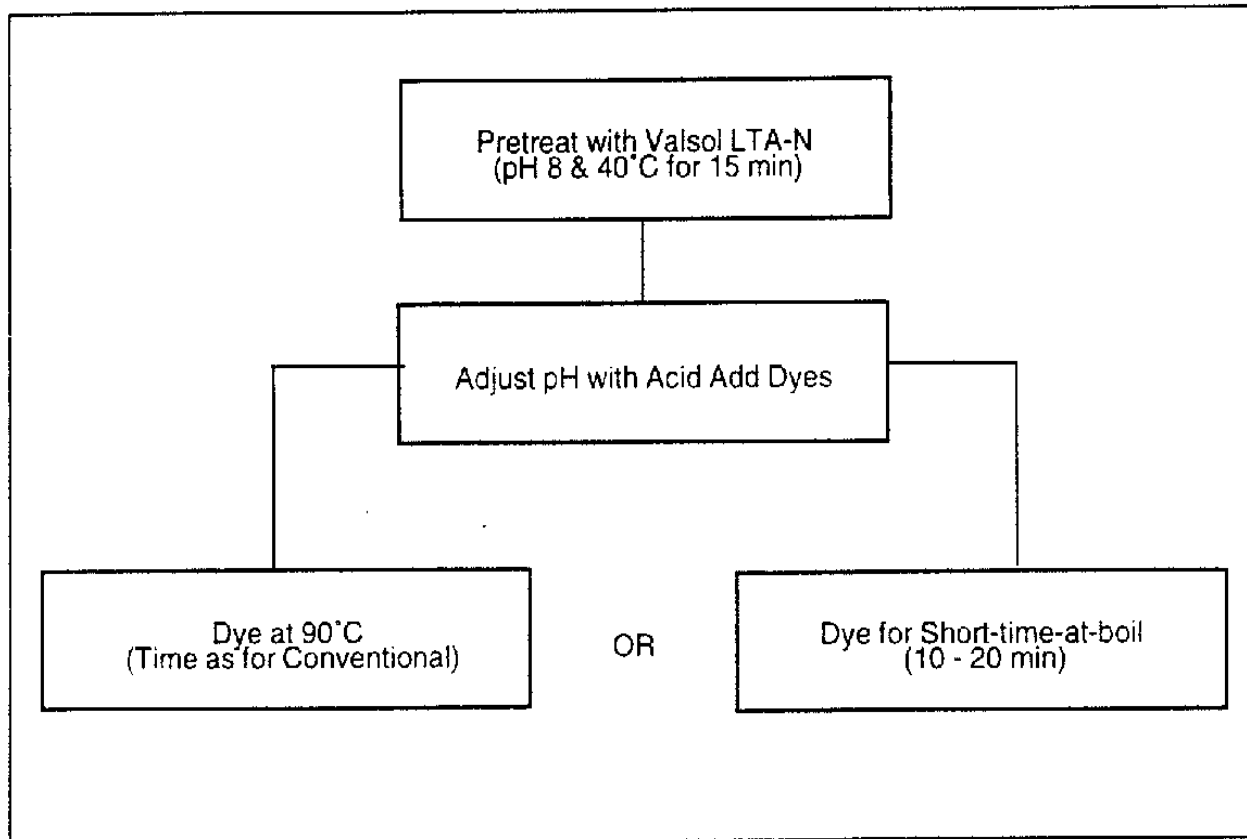


# Consequences of loss of fibre strength during dyeing

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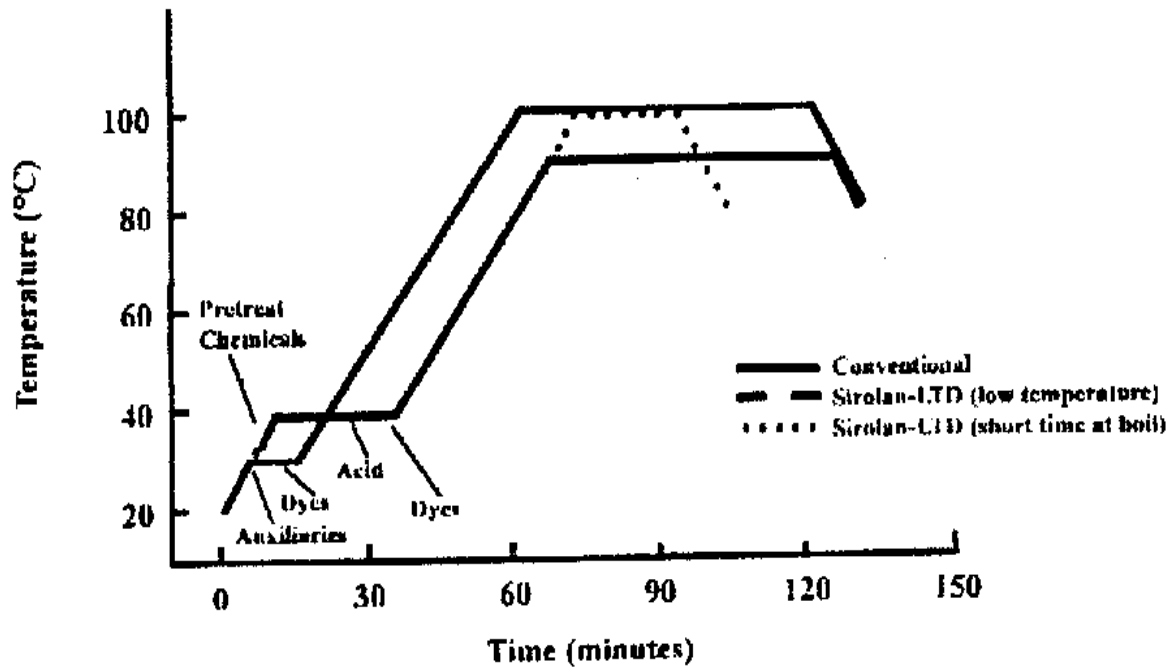
- Fibre breakage in carding and combing increases.
- Yarn and fabric breaking load and extension at break decrease.
- Weaving efficiency is reduced.
- Product range is reduced, especially with articles requiring fine yarns.

# Dye at temperatures below the boil or for a short time at the boil



# Dye at temperatures below the boil or for a short time at the boil

CONVENTIONAL AND SIROLAN-LTD  
DYEING METHODS



# Advantages of the Sirolan-LTD process

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Decreased fibre damage.

Better exhaustion of dyes and insect-resist agents.

Less yellowing in dyeing.

Excellent coverage of tippiness.

Greater bulk and openness of loose stock.

Processing benefits

Decreased effluent load.

Brighter shades.

Better quality dyeings.

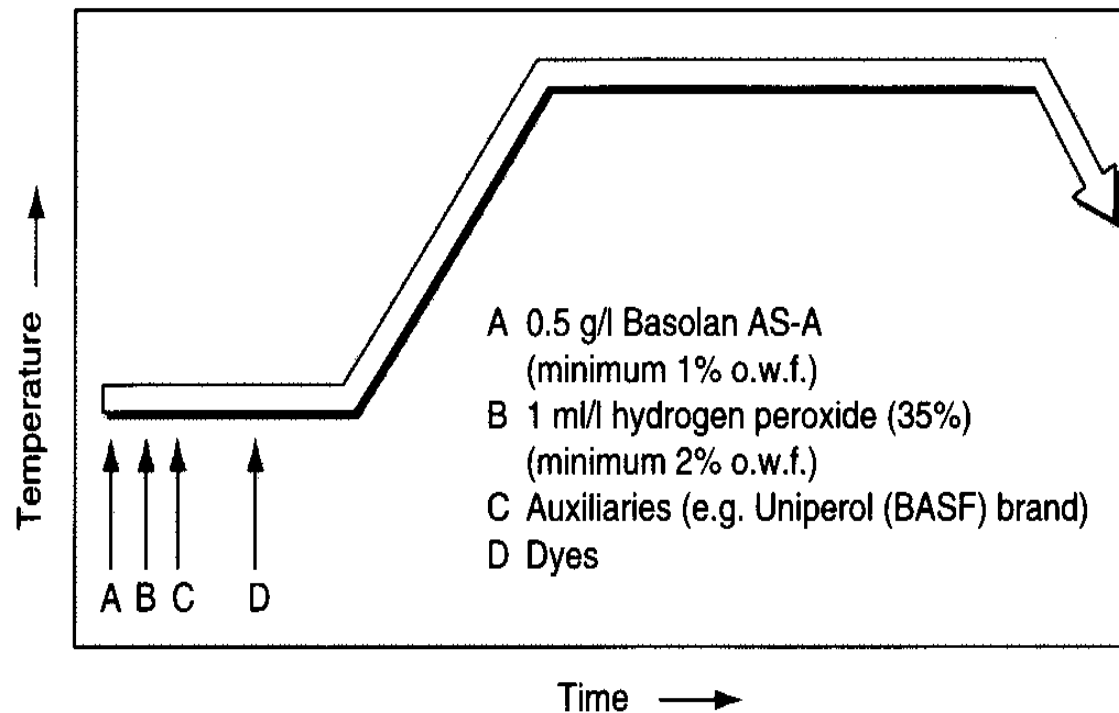
Easier drying and blending.

# Anti-setting dyeing technology

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- Anti-setting dyeing technology restricts the permanent setting of wool while it is being dyed.
- Chemical agents are used to hinder the thiolate-disulphide exchange reaction in wool.

# Anti-setting dyeing technology



**Dyeing in the presence of Basolan ASA and hydrogen peroxide.**

# Benefits of anti-setting dyeing technology

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- Loose fibre or top
  - Improved processing performance in carding and spinning.
  - Increased yarn elongation, hence increased knitting and weaving efficiency.
  - Increased tensile strength of woven fabric.
  - Improved handle of knitted goods.
- Yarn (package or hank)
  - Increased bulk of knitting yarn.
  - Reduced loop distortion in knitted fabric.
  - Increased yarn elongation, hence increased knitting and weaving efficiency.
  - Increased tensile strength of woven fabric.
  - Improved handle of knitted goods.
- Fabric
  - Reduced hygral expansion, hence to improved garment appearance.
  - Improved surface appearance, with less severe running marks.
  - Increased tensile strength and abrasion-resistance.
- Shade brightening
  - Compared with conventional wool dyeing, pale and medium shades are brighter because there is less yellowing and greying of the base fibre.
  - Slightly better light fastness because of the brighter base fibre.

# Improved yarn bulk with anti-setting dyeing technology (Basolan ASA method)



Effect of Basolan AS on the Bulk of Package-dyed Wool Yarns



# Extra benefit of anti-setting dyeing technology

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The benefits are similar to those of low temperature dyeing but, in addition, this type of technology has another new potential application:

- particularly the dyeing of wool-polyester blends at temperatures up to 120°C, the protective effect is significantly better than with older-style formaldehyde-release protective agents.

# 5. Innovations in dyeing modified wool fibres

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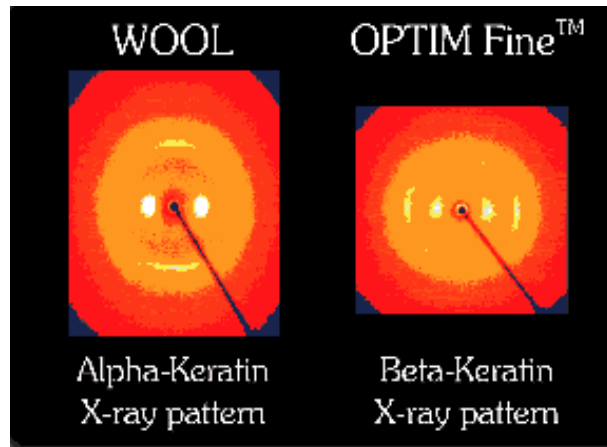
# Making wool fibres thinner

OPTIM™  
SUPREME LUXURY FIBRES

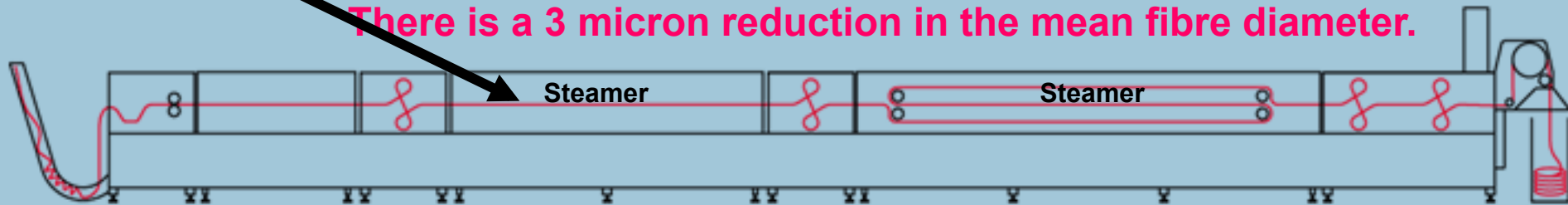
X-ray diffraction shows that the wool has been changed from  $\alpha$  to  $\beta$  keratin



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



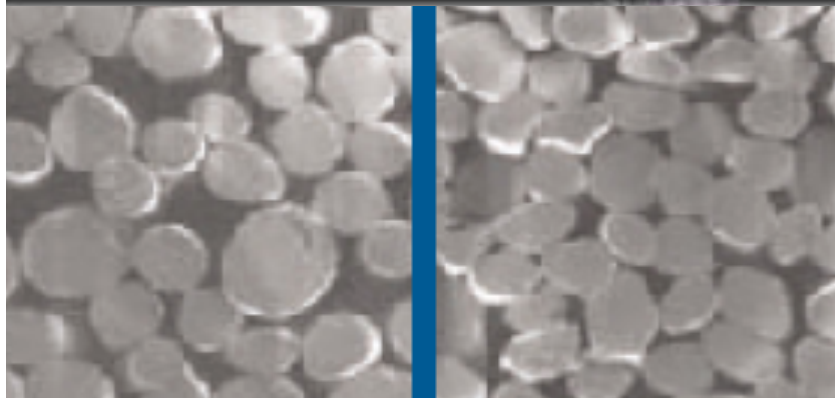
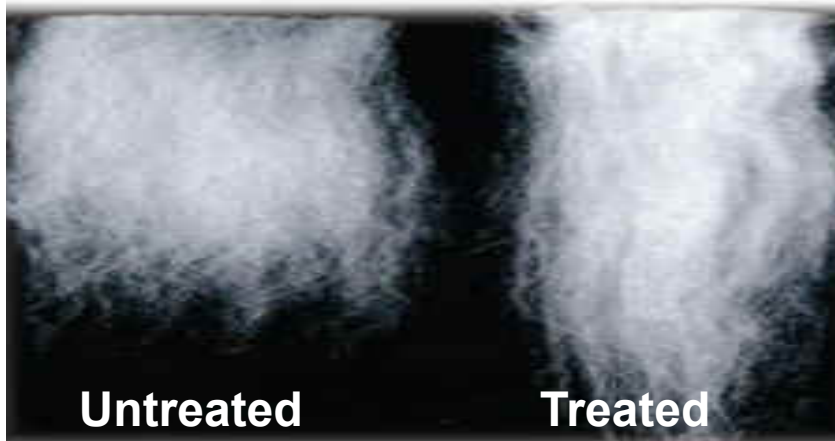
There is a 3 micron reduction in the mean fibre diameter.



# Optim fibre

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



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

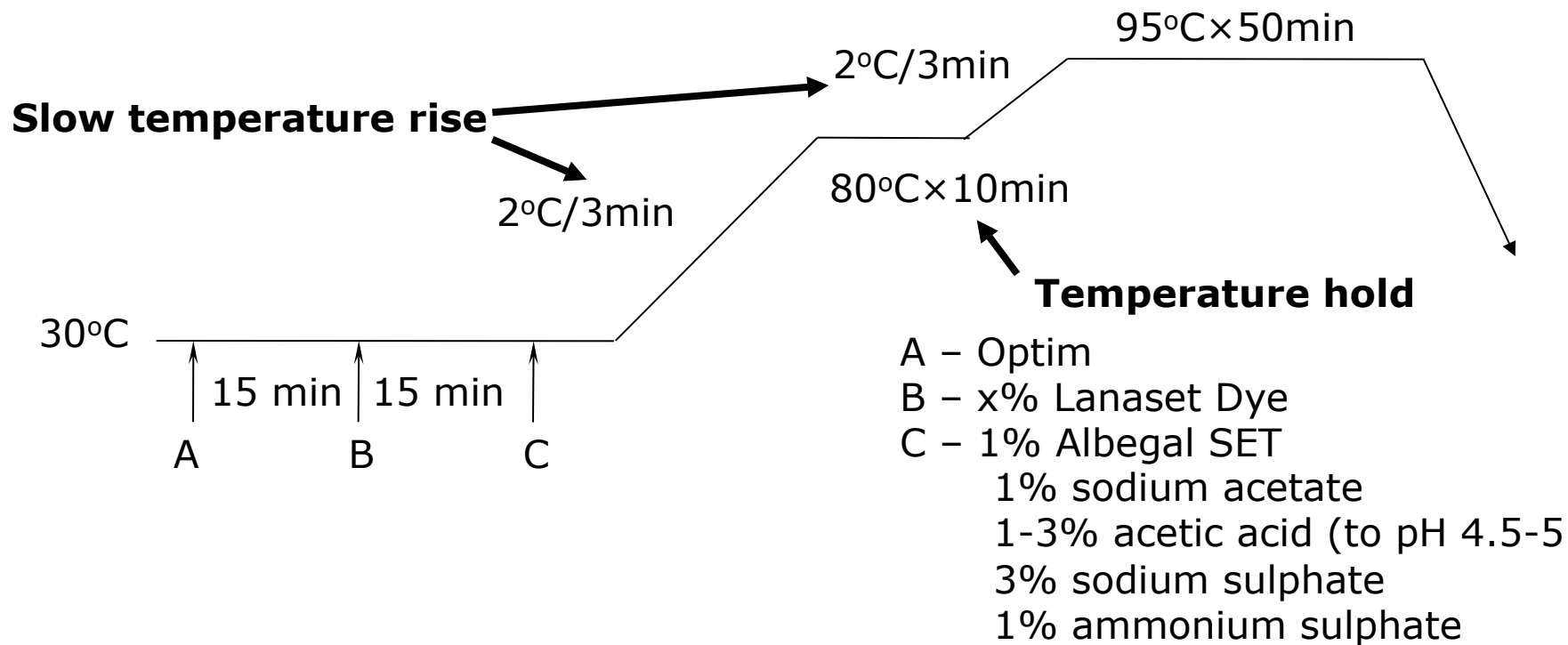


# Dye uptake by Optim Fine

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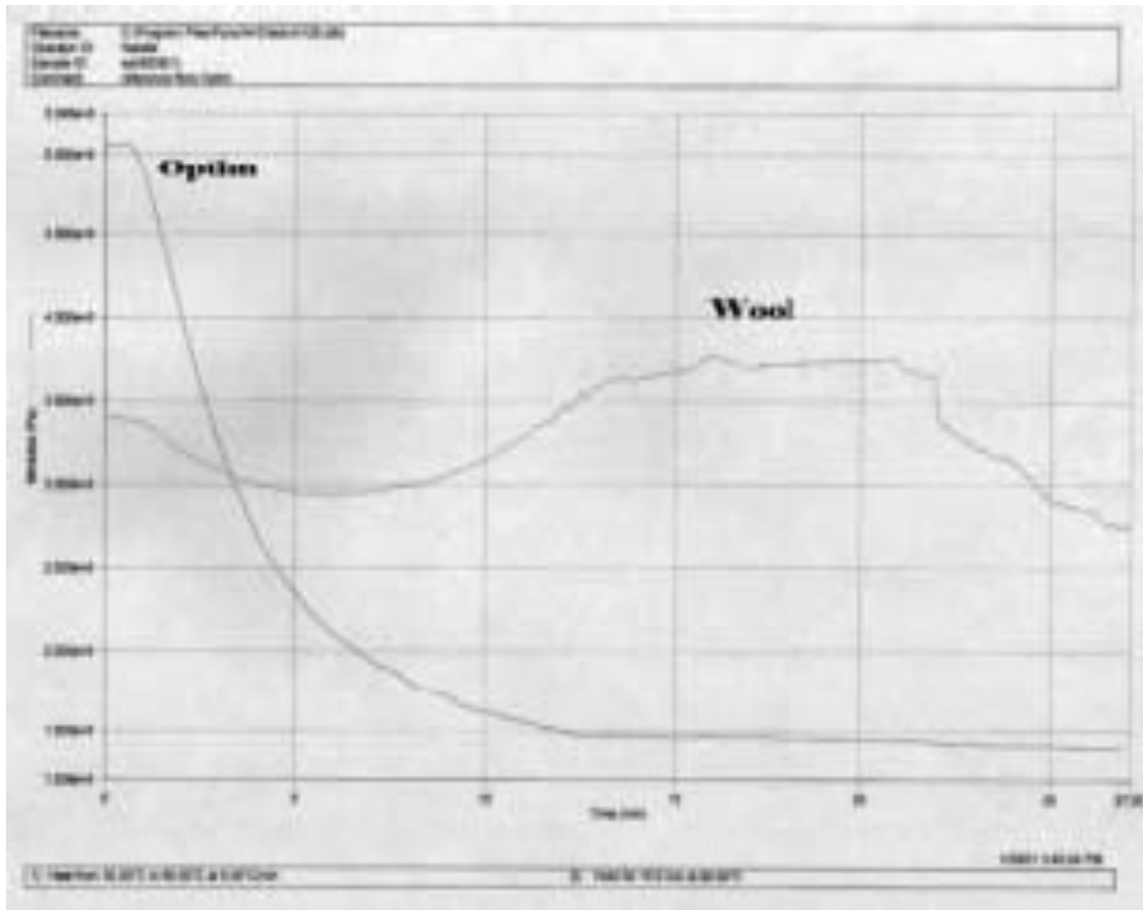
- The rate of dye uptake is faster than with normal wool.
- One method that has been used for Lanaset dyes is:
  - start at a low temperature
  - use a slow rate of temperature rise
  - and hold the temperature at 80°C before taking it to the boil.

# Dyeing Optim Fine with Lanaset dyes



The Dyeing properties of Optim Fine Wool Products, Wei L. *et al.*, *Fangzhi Xuebao* 25 (6) (2004) 53.

# The loss of stiffness of Optim fibre in water as the temperature rises



There is a marked decrease in the modulus of the wet Optim Fine fibre as the temperature of the dyebath is increased, compared with normal wool.

Note: Fibre samples heated from 30°C to 98°C (at 5°C/min) during 13.6 minutes and maintained at 98°C for a further 13.4 minutes.

# Problems to be overcome in dyeing Optim Fine

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- The progressive decrease in fibre stiffness with increasing temperature can result in severe deformation of tops or yarn packages. Packages can collapse on the dyeing spindles so that dye liquor channels around rather than through the packages, and this results in grossly unlevel dyeing.
- In piece dyeing, stretching of the fabric must be avoided at all costs.
- CSIRO Textile and Fibre Technology has developed modified dyeing methods for Optim Fine fibre in top, yarn and piece form. Detailed information on these methods can be obtained from TFT.



# 6. Innovations in bleaching wool

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# Combined oxidation and reduction bleaching

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- The best available technology at present for producing a bleached white on wool and chlorine/Hercosett wool is with a combined oxidative/reductive procedure.
- Oxidation is carried out with hydrogen peroxide using Tinoclarite WO as stabiliser (as recommended by Woolmark),
- Reduction is carried out by the ColorClear bleaching treatment (Rohm and Haas).

**Ref: COLORCLEAR TECHNOLOGY, A NEW METHOD OF WHITENING OF WOOL, MACHINE WASHABLE WOOL AND WOOL/COTTON BLENDS, S M Smith<sup>1</sup>, D J Westmoreland and H P Schoots, *Proc 11th Int. Wool Text Conf.*, Leeds, UK, (2005).**

# Peroxide bleaching with Tinoclarite WO

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- Set bath cold with:
  - Tinoclarite WO (Ciba) 4g/L
  - run for 10 minutes, add
  - hydrogen peroxide (35%) 25mL/L (pH 10-10.5).
- Raise temperature to 50°C and hold for 60 minutes.
- Drain and rinse.
- Acid sour.

# ColorClear reduction bleaching method

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ColorClear solution contains sodium borohydride and stabilisers.

- Set bath at 40°C with:
  - 2.0 g/L ColorClear (Rohm and Haas)
  - 8.0 g/L Catalyst 100
  - 0.5 g/L Wetting agent/detergent
  - Acetic acid to pH 5.5.
- Run 10 minutes.
- Raise temperature to 60°C and hold for 60 minutes.
- Drain and rinse.

# Lightfastness of bleached wool

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- The lightfastness of bleached whites on wool remains around 4 in the dry state and is lower in the wet state.
- Bleached goods are best not exposed to direct sunlight, especially when wet.
- More improvements in the stability of bleached whites are required.

# 7. Innovations in improving the light-fastness of dyeings

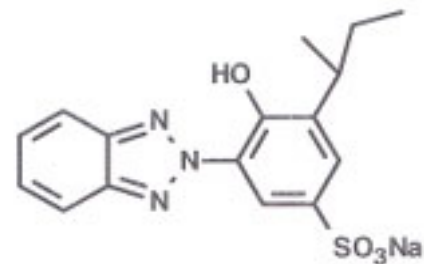
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# The lightfastness of coloured wool

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- The base colour of wool is not very stable to sunlight; initial bleaching is followed by yellowing.
- The lightfastness of many dyes is somewhat lower than with other fibres.
- The light stability of bleached wool is too low for many products.
- These problems arise because of the wool polypeptide contains reactive amino acids that are activated by the ultra-violet component of sunlight.

# Cibafast W (Ciba)



- This compound absorbs UV light at wavelengths that are damaging to wool.
- The effectiveness of this compound was discovered by workers at CSIRO Division of Protein Chemistry.
- The compound is applied together with dyes.
- Light fastness of dyeings with selected metal complex and acid dyes in dark and pale shades is improved.
- Fibre damage on prolonged exposure at high ambient temperatures is reduced.
- The rate of yellowing of unbleached and bleached wool is reduced.



# Cibafast W

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## Characteristics:

- **Very good exhaustion and even uptake under the usual dyeing conditions for wool.**
- **Miscible with water, non-foaming, low viscosity, stable in the dyebath, good storage stability.**

## Required amount:

- **Exhaustion -**
  - **3 - 4 % Cibafast® W liquid, depending on liquor ratio and requirements.**
- **Continuous steaming -**
  - **7.5 g/l Cibafast® W liquid, at 400% pick-up.**
- **Aftertreatment -**
  - **3 - 4 % Cibafast® W liquid.**

# Cibafast W

Dyeing addition	Lightfastness			
	Pale grey	Rose	Pale violet	Pale blue
None	5	4-5	4-5	4-5
+ 2% Cibafast W	6	6	6	6

Shade	Dyes	% (owf)
pale grey	Lanaset Grey G Lanaset Bordeaux B	0.04 0.004
rose	Polar Red RLS 200 Polar Brilliant Blue RLS 160 Polar Yellow 4G 160	0.04 0.0025 0.002
pale violet	Polar Brilliant Blue RLS 160 Polar Red RLS 200	0.01 0.005
pale blue	Erionyl Blue M-RW Erionyl Blue 7G 200	0.02 0.02

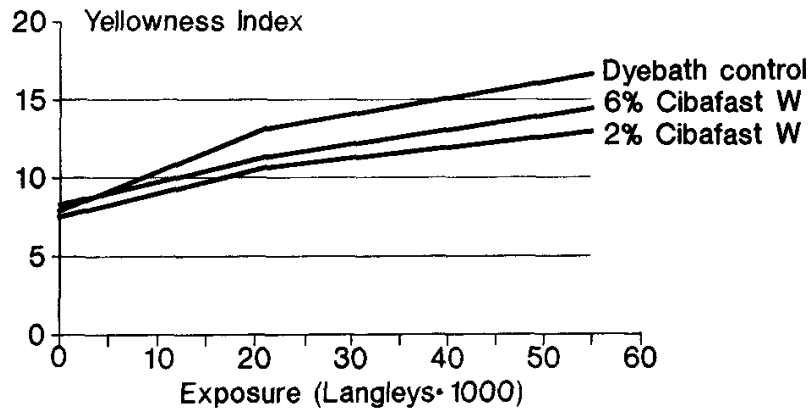
There is an increase in lightfastness of pale shades of 1 to 1.5 rating points in the presence of Cibafast W.

In practice, the actual improvement depends on the dye and the initial yellowness of the wool.

# Cibafast W

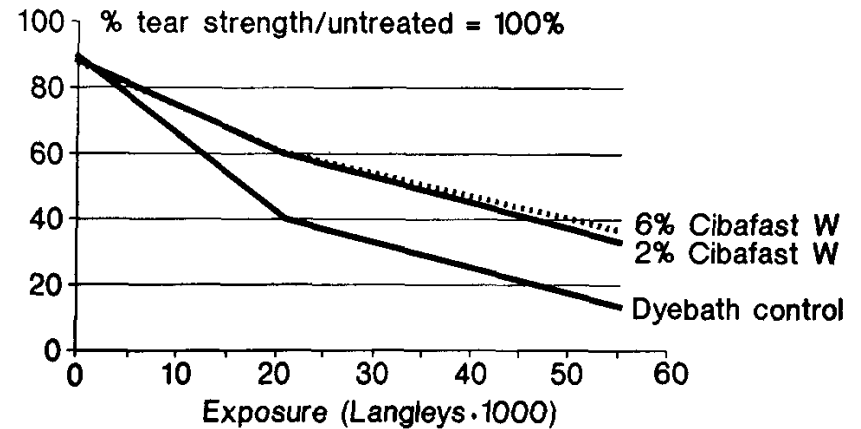
Photoyellowing of plainweave fabrics  
after exposure to sunlight under glass

(Allunga QLD, March–August 1989)



% Tear strength of plainweave fabrics  
after exposure to sunlight under glass

(Allunga QLD, March–August 1989)



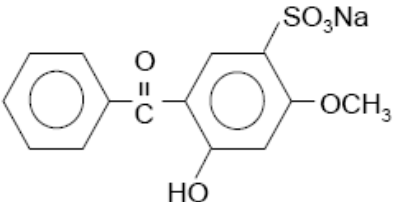
With Cibafast W treatment:

- photoyellowing is reduced
- tear strength is lost more slowly after sunlight exposure.

# Other sulphonated phenolic compounds, similar to Cibafast W, are available from other sources

## UV Light Stabilizers: TYHOL-5(Benzophenon 5)

### Specifications

Structural formular	
Chemical name	2-Hydroxy-4-methoxybenzophenone 5 Sodium Sulfonate Sodium Hydroxymethoxy benzophenone Sulfonate
INCI name	Benzophenone-5
CAS No.	6628-37-1
Molecular formular	C <sub>14</sub> H <sub>11</sub> O <sub>6</sub> S.Na
Appearance	Pale yellowish white granular powder
Assay (Dried basis)	99% min by absorbance @225nm
Loss on drying	3.0% max
Residue on ignition	23~ 27%
pH value	5 ~ 7%

### Product Protection

- Prevent colorant fading in transparent packaging
- Stabilizes the viscosity of gels based on polyacrylic acid(i.e. carbopol) when exposed to UV radiation
- Improve the stability of fragrance oils
  - ⇒ Conditioning Shampoo
  - ⇒ Body Cleanser



### Hair Protection

- Prevent brittle or bleached hair due to UV
  - ⇒ Hair gels & Hair setting lotions
  - ⇒ Mousses & Hair sprays

### Sun Care

- Water soluble Organic UV filter
  - ⇒ Sun Protection Lotion (O/W)

### Textiles

- Improve color fastness of dyed fabrics
- Prevent yellowing of wool
- Prevent discoloration of synthetic fibers

# 8. Innovations with digital printing technology

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# Ink jet printing

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- This was **first introduced for carpets**, where only low resolution prints are required.
- As ink jet printers have developed for **paper printing**, textile machines have piggybacked on the **technology**.
- The main difference between printing textiles and paper is that **greater quantities of ink are needed for textiles**.
- The **resolution of printing on textiles is slightly lower** than on paper and is ultimately related to the surface structure.
- In principle, jet printing **could replace any direct printing method** with any type of dye or pigment.
- The method has the advantage that it **does not require contact** with the textile surface.
- Because of the high resolution possible, **discharge and resist printing may become redundant**.

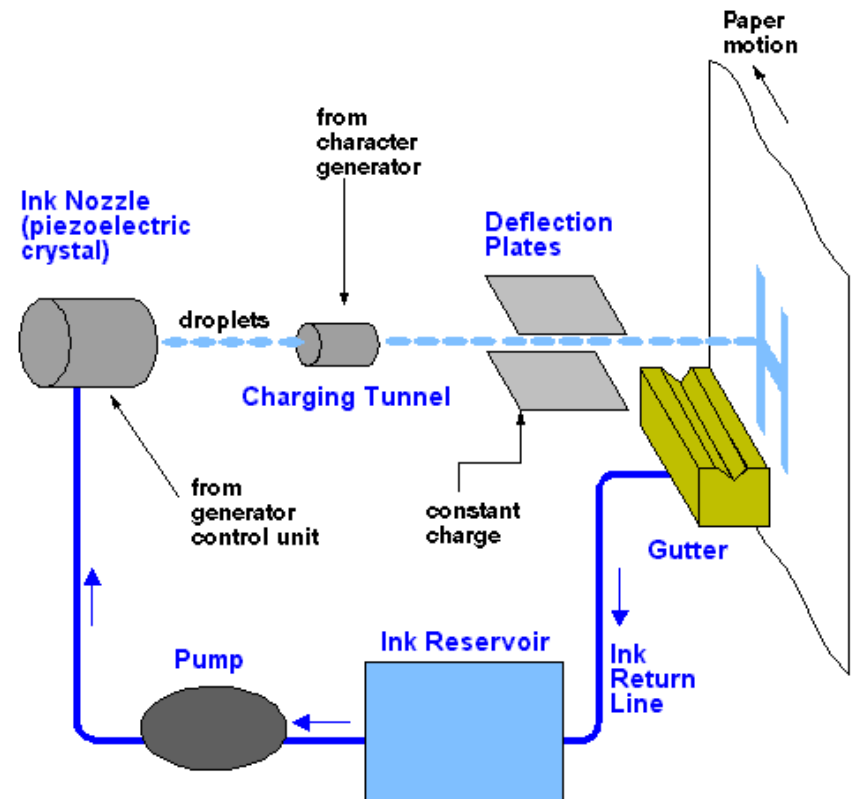
# Markets for Digital Textile Printing

- ❑ **Carpets / Carpet Tiles** (Milliken, Zimmer)
- ❑ **Sampling & Proofing** (Stork, Iris, Epson, Mimaki)
- ❑ **Outdoor Banners (Mesh) & Building Wraps**
- ❑ **Scarves & Ties** (Mimaki, DGS, Sophis)
- ❑ **Garments** (T-shirts, Sportswear, Sportsgear)
- ➔ ❑ **Short-run Apparel Printing**
- ❑ **Theatre Backdrops, Canvas/Mesh** (NUR, Vutek, Scitex)
- ❑ **Automotive Fabrics** (Seiren)
- ❑ **Flags & Banners** (Color Wings, Xerox, Gretag, Zimmer)

# Continuous ink jet print head

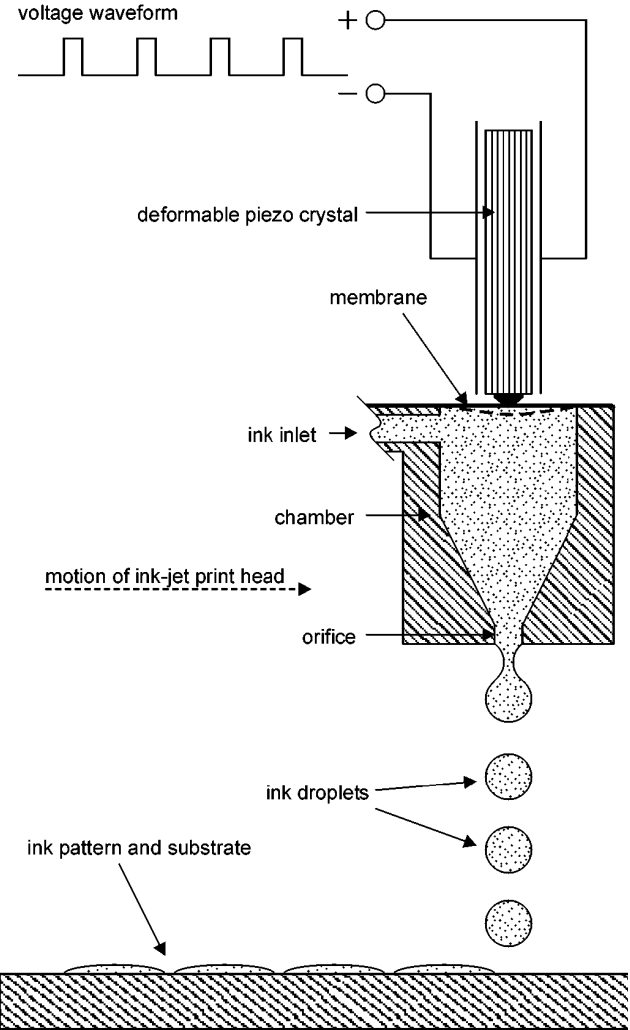
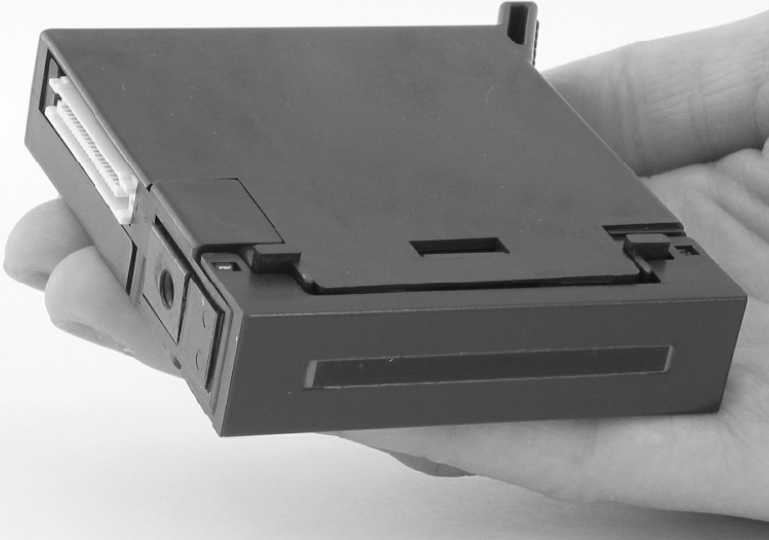
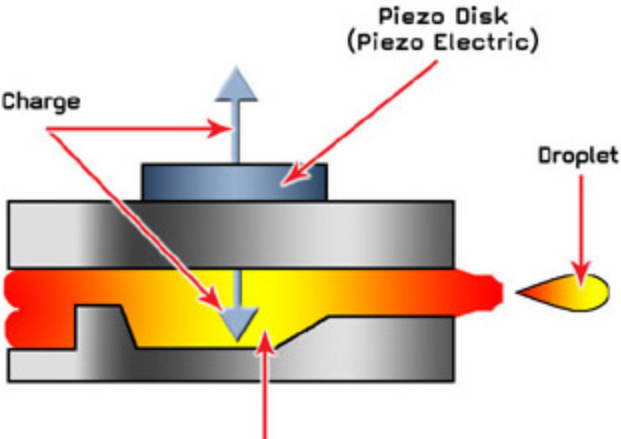
From Computer Desktop Encyclopedia  
© 1998 The Computer Language Co. Inc.

This method sprays continuous droplets of ink that either reach the paper or wind up in the return gutter. The nozzle uses a piezoelectric crystal to synchronise the chaotic droplets that arrive from the pump. The charging tunnel selectively charges the drops that are deflected into the gutter. The uncharged droplets make it to the paper. The diagram depicts a single nozzle.





# Drop on demand piezo print heads



# Dupont Artistri digital jet printer

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# Digital jet printers

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Mimaki TX2



Ichinose 2020

# Reggiani DReAM digital printer



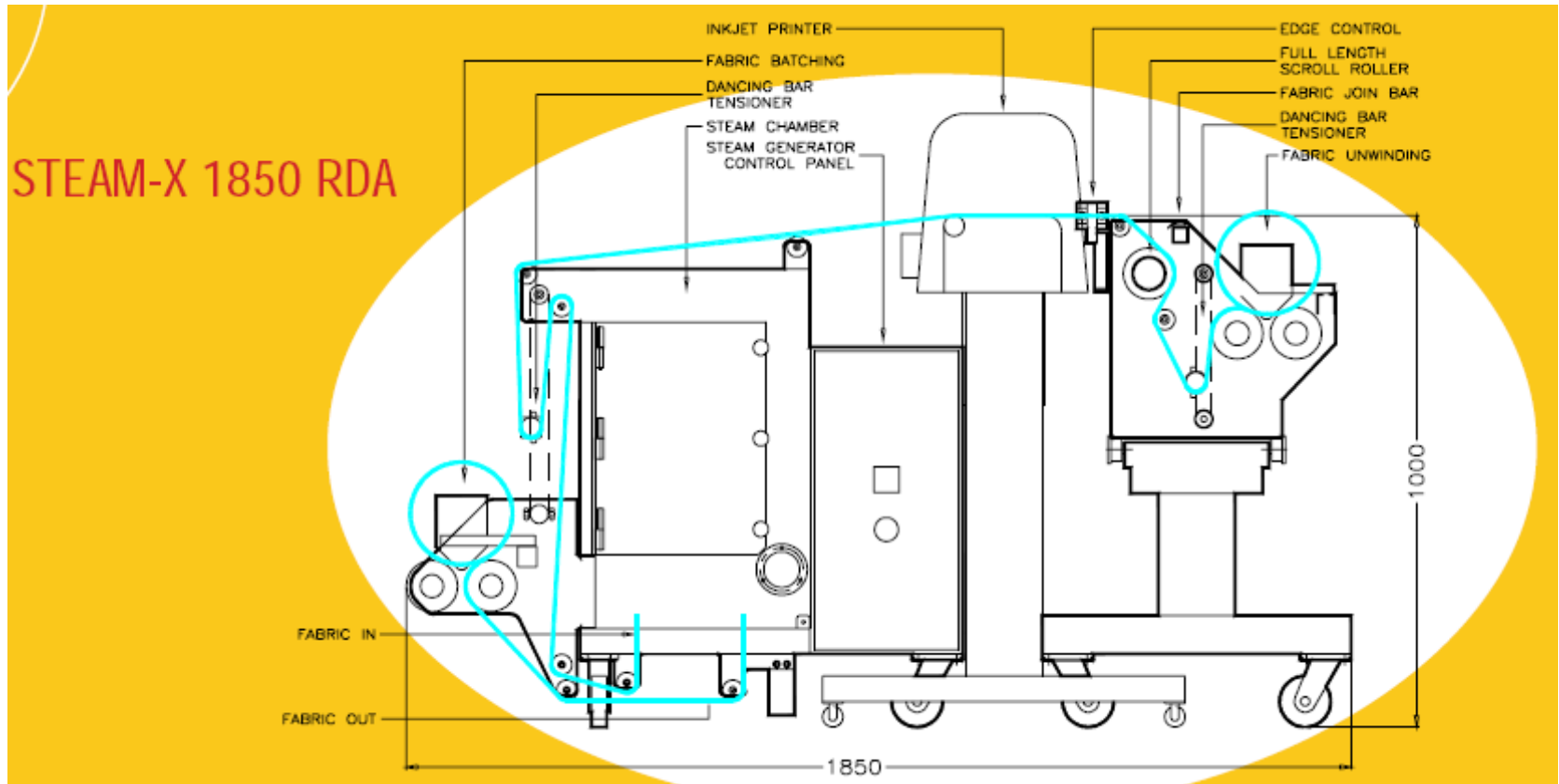


# Inks for digital printing

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- Most major dye makers can supply specially formulated inks for different types of print heads and fabrics.
- Inks can contain pigments, dyes or resist agents, depending on the textile to be coloured.
- After printing, fabric may be dried and the dyes or pigments fixed using methods appropriate for the fibre and type of colourant.
- In the case of wool, conventional milling, premetalised and reactive dyes are printed on pretreated fabric (chlorinated or equivalent).
- After printing, the prints are fixed by steaming, then the fabric is washed off, as with other direct printing methods.

# Stork digital printer and Rimslow STEAM-X 1850 SDA steamer



# Digital print washer

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The Rimslow Wash-X designed for digital printers washes and dries fabric continuously from roll to roll.

# Rimslow digital printer and steamer

## Operating parameters

	Units	Natural Fibre (reactive Dyes)	Silk (Acid Dyes)	Polyester (Disperse Dyes)
Fabric Maximum width	mm	1830		
Steaming Temperature	C	102		175
Maximum Speed	m <sup>2</sup> /hr	44	22	110
Steaming time	min	15	30	6
Fabric length inside the Steamer	m	6.0		
Machine Length	m	2.0		
Machine Width	m	2.5		
Machine Height	m	1.3		
Water Tank Capacity	L	20		
Power Consumption	kW	7.0		
Fabric Roll Diameter Max	mm	200		
Fabric Feeder	-	included		



# 9. The future

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# The future

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'It is not the strongest of the species that survives, not the most intelligent, but the one most responsive to change.'

Charles Darwin

# The future

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- The last half century has seen wool changing from a commodity textile fibre into a specialty niche fibre because of:
  - the relatively high cost of production
  - limitations to possible fibre modifications.
- The survival of the wool textile industry will depend on its ability to find markets for products with unique customer appeal.
  - A future move away from petroleum-based textile fibres towards renewable and more ecologically benign fibre production methods may benefit wool.
- Many technical innovations will occur as a result of spin-off from developments for other textile fibres.
- When wool-specific innovations have occurred, they have been generated by research financed from levies on wool production, principally within Australia. Will this continue?