Innovation Module 2 P R Brady May 2006

Lecture 3.06, Innovation: Colouration

Course notes

(These are intended for use in conjunction with the Powerpoint presentation for this module.)

Innovations

Colouration is subject to general trends within the textile industry. Many of the current and future changes will be determined by economic priorities that have become well established during recent times. The major requirements are to reduce the cost of processing and to introduce new profitable products and processes.

1. Innovations in processing

The costs of processing can be decreased by reducing inventory, minimising labour, eliminating operator error, increasing the efficiency of machinery, minimizing waste and shortening of processing times. This has lead to:

- late-stage processing,
- just in time production,
- increasing levels of automation in the dyehouse,
- right first time dyeing.

Coloration is moving to later stages in the processing sequence in order to save on inventory costs in processing and to reduce processing times. This means that loose stock and top dyeing are becoming less important because of the long lead times required in production and the use of old fashioned blending technology to obtain desired colours. Blending of separately dyed lots was a way of compensating for the poor control that dyers had over colouration processes. With manually operated dyeing machines, and the lack of supplementary supporting technologies, such as pH control and instrumental colour correction, it was very difficult to carry out dyeings with good consistency and reproducibility.

As colouration moves to later stages in production and yarn, piece and garment dyeing become more important, there is less leeway for error and this creates a demand for sophisticated and robust production technologies. In fact, colouration at late stages in processing has been dependant on the development of:

- 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.

The economic pressures that have forced the trend to late stage processing have also been responsible for implementation of “just in time” processing.

When we speak about *automation* in textile dyeing, we mean at least one (or all) of the following steps:

- programmable process control (by microprocessors) of the machinery;
- dissolving and dispensing of the dyes, pigments and chemicals in a central colour kitchen;
- computer-controlled weighing of goods with automated stock control;
- colour measurement, computerized colour matching in the lab and in production;
- robotic systems for loading and unloading machines;
- computerized management using a central computer network.

Many dyehouses have been able to gain sufficient control of their production methods to ensure that a very high proportion of dyeings are "right first time" and require no manual intervention to compensate for errors.

Highly automated dyehouses only require staff only to supervise, program and maintain the automated equipment required to operate the dyehouse. The job of a dyer in this situation requires the qualifications of an engineer as well as a colourist. In some sectors of the industry, it has already been possible to operate lights-out dyehouses – particularly for top and yarn dyeing. Top and yarn dyeing are more easily automated because package sizes can be easily standardised. Automated fabric dyeing is more difficult to implement and is easier to carry out with fabric in open width using batch-to-batch equipment such as continuous dyeing ranges, beam dyers and jiggers. Wool is not dyed by continuous methods because of the short runs required in most shades but beam and jigger dyeing are technically possible in appropriately designed equipment.

The benefits from dyehouse automation are as follows:

- 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. 10-15% savings in dyes, pigments and chemicals.
- Lower discharges with less pollution and lower cost of effluent treatment.
- Colour measurement and computerized colour matching can save up to 30-40% in cost of dyes by reduction in inventory and development of less expensive dye combinations for particular end-uses.
- The costs of automation are relatively low, typical return on investment figures are in the range of 3 months to 1 year, not including the value of quality and reliability improvements.

2. Innovations in dyes for wool

The development of synthetic dyes was the inspiration for the development of organic chemistry in the 19th century. Today the emphasis in dyeing is no longer on the chemistry or structure of dyes but on their functionality, compatibility and ease of use. Dyes are not necessarily grouped according to chemical type. Rather, modern colorants are made up of single dyes and mixtures of dyes that give desired dyeing behaviour and fastness properties. The trends in dye development are towards cheaper, more washfast products, with stronger colours, which can be synthesized and applied to textiles with minimum pollution of effluent. As far as wool is concerned, the total number of dyes made has contracted considerably in recent years and the emphasis on dye research has been on products for synthetic fibres.

Formerly, information on dyes was rather limited and available only in printed form and in colour cards, now a very comprehensive range of data is available in electronic formats, and colours can be reproduced with reasonable accuracy on computer screens. Some dye manufactures offer free colour matching services and provide programs for use with their dyes to assist in selection of the most economic dye recipes to match required shades within prescribed tolerances regarding wet fastness, lightfastness, crocking fastness, metamerism and the effluent pollution loads from heavy metals and unexhausted colour.

One recent factor that has impinged on dyeing practice is the appearance of eco-labels for textiles. For example, the Ökotex label was founded in 1993 by the Austrian Textile Research Institute. The aim has been to provide consumers with a quality label that ensures that products are free of harmful substances. 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 in Europe, together with associate institutes over the world which can test textile products and award the labels. The list of potentially harmful substances that the Okotex 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 (a few specific types based on harmful amines),**
- **chlorinated organic carriers,**
- boicidal finishes,
- flame retardent finishes,
- **colour fastness,**
- emission of volatiles,
- odours.

The categories in bold above can be involved in dyeing. Eco labels have lead 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. There is a perceptible trend towards the use of multifunctional reactive dyes which make it possible to obtain brighter dyeings, with high wet fastness properties, and low pollution loads. Wool-polyester blends need to be dyed with special carriers, or above the boil in the presence of special protective agents for wool. An example of a new range of dyes developed to meet eco requirements are Sandolan MF (metal free) dyes, which are intended to replace metal complex dyes in some applications, such as for carpets. Reactive dyes in general are gradually replacing chrome dyes in applications where high levels of wet fastness are required. Examples of new reactive dye ranges are Lanasol CE – Ciba and Realan - DyStar. In all these cases, the new groupings are mostly composed of dyes already in production which have been selected for their functionality and compatibility in the new ranges.

3. Innovations in dyeing machinery for wool

Yarn dyeing has made many advances in terms of innovations 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 is to press-pack parallel sided, precision wound, packages and to dry using radiofrequency or rapid hot air dryers.

The traditional open winch for dyeing wool fabric had many disadvantages with poor circulation, inadequate temperature control and difficulties with rig marks. Piece dyeing machinery for wool has piggybacked on developments for jet dyeing of synthetics, but 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 because wool is prone to become felted and permanently set while it is being dyed. The use of modern machines is critical to reproducibility and the use of new dyeing technologies that are dependent on accurate temperature control.

4. Innovations in dyeing methods to protect the fibre

Unlike many other textile fibres, wool is damaged by dyeing in water because of chemical degradation of the keratin polypeptide. The consequences of loss of fibre strength during dyeing are:

- increases in fibre breakage in carding and combing,
- decreases in yarn and fabric breaking load and extension at break,
- reduced weaving efficiency,
- reduced product range, specially with articles requiring fine yarns.

Two recently developed low damage dyeing methods have been developed to overcome this disadvantage. These are an improved low-temperature dyeing auxiliary and the new and quite unexpected discovery of so-called anti-setting dyeing technology.

The latest low-temperature dyeing method was developed at CSIRO TFT and commercialized in partnership with ICI. It is called the Valsol LTA-N method and the details are given in Figure 1.

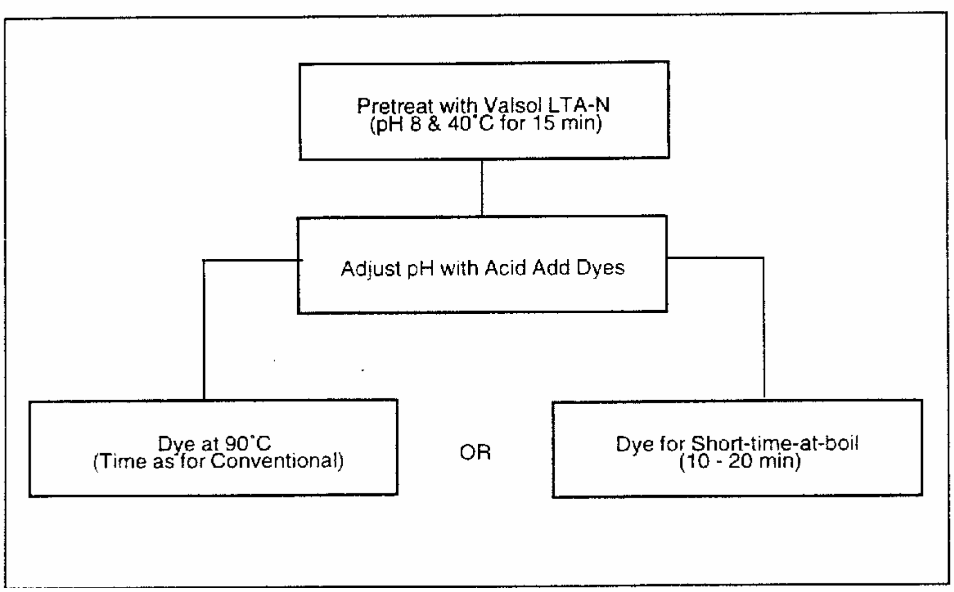

Figure 1 The Valsol LTA-N low damage dyeing method.

Advantages of the Sirolan-LTD process are:

- decreased fibre breakage in processing,
- better exhaustion of dyes and insect-resist agents,
- decreased effluent load,
- less yellowing in dyeing,
- brighter shades,
- excellent coverage of tippiness,
- better quality dyeings,
- greater bulk and openness of loose stock,
- easier drying and blending.

Anti-setting dyeing technology restricts the permanent setting of wool while it is being dyed. Chemical agents are added to the dyebath to inhibit the thiolate-disulphide exchange reaction from taking place in wool while it is being dyed. Details of the Basolan ASA method is given in Figure 2.

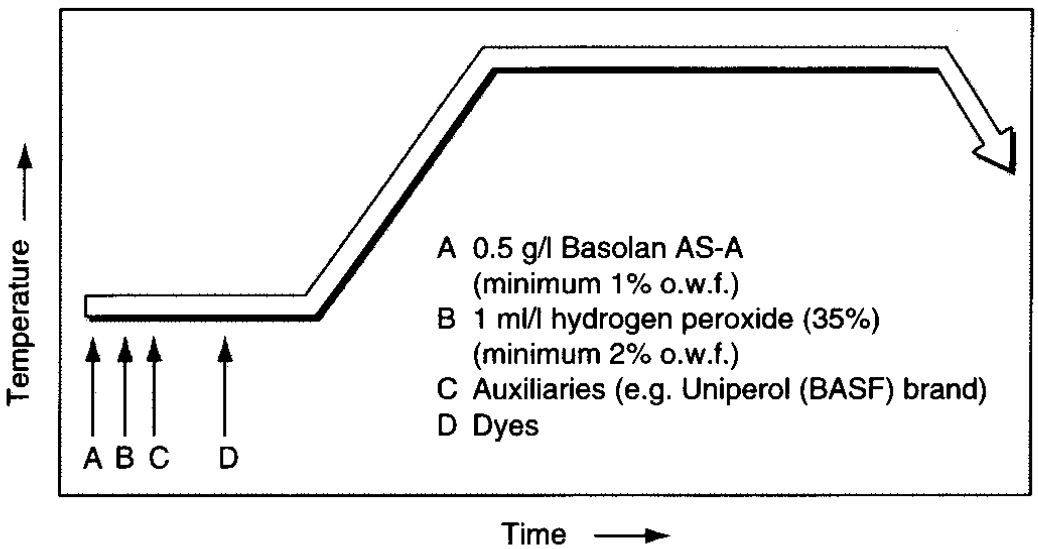

Figure 2 Anti-setting dyeing technology - dyeing in the presence of Basolan ASA and hydrogen peroxide.

Dyes need to be selected for stability to the treatment conditions. Lists of suitable dyes can be obtained from BASF. The following advantages have been found in trials of the technology under industrial conditions.

- <u>Wool dyed as loose fibre or top</u>
    - Improved processing performance in carding and spinning.
    - Increased yarn elongation, leading to increased knitting and weaving efficiency.
    - Increased tensile strength of woven fabric.
    - Improved handle of knitted goods.
- <u>Wool dyed as yarn (package or hank)</u>
    - Increased bulk of knitting yarn.
    - Reduced loop distortion in knitted fabric.
    - Increased yarn elongation, leading to increased knitting and weaving efficiency.
    - Increased tensile strength of woven fabric.
    - Improved handle of knitted goods.

- Wool dyed as woven fabric
    - Reduced hygral expansion, leading 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 noticeably brighter because there is less yellowing and greying of the base fibre.
    - Slightly better light fastness because of the brighter base fibre.

The above benefits are similar to those of low temperature dyeing but, in addition, this type of technology has another new potential application - the dyeing of wool-polyester blends at temperatures up to 120°C. The protective effect of Basolan ASA technology is significantly better than with older-style formaldehyde-release protective agents.

Now that the principle has been established, other anti-setting treatments and dyeing assistants have been identified and developed. These include Miralan HTP (Ciba) and a number of compounds investigated at Leeds University.

5. Innovations in dyeing modified wool fibres

Wool product opportunities based on changes to the shape and internal chemistry of the fibre have proved to be severely limited. The recent development of Optim Fine fibre, at CSIRO Textile and Fibre Technology, represents a breakthrough, because this new type of thinner fibre is produced by chemical and physical treatment of normal fibres. Optim Fine is made by first treating wool sliver with a reducing agent (such as sodium bisulphite); the sliver is then twisted into a rope which is stretched by around 40%; the stretched fibres in the rope are then permanently set in steam. Compared with the starting wool, the stretched fibres are longer, finer, more lustrous and have more angular cross sections. Typically, the process results in a reduction in the fibre diameter of 3 to 4 microns.

Optim Fine fibres have different dyeing properties to conventional wool fibres and these provide new challenges in processing. The fibre is whiter than conventional wool, so brighter colours, particularly in pastel shades, can be obtained. As with polyester microfibre, because the fibres are finer than normal, higher add ons of dye are required to match any given shade. Also, the rate of dye uptake is faster than with normal wool, so dyeing methods need to be modified. One method that has been used for Lanaset dyes is to start at a low temperature, use a slow rate of temperature rise, and hold the temperature at 80^{o}C before taking it to the boil, as illustrated in Figure 3. [The Dyeing properties of Optim Fine Wool Products, Wei L. *et al, Fangzhi Xuebao* **25** (6) (2004) 53.]

.

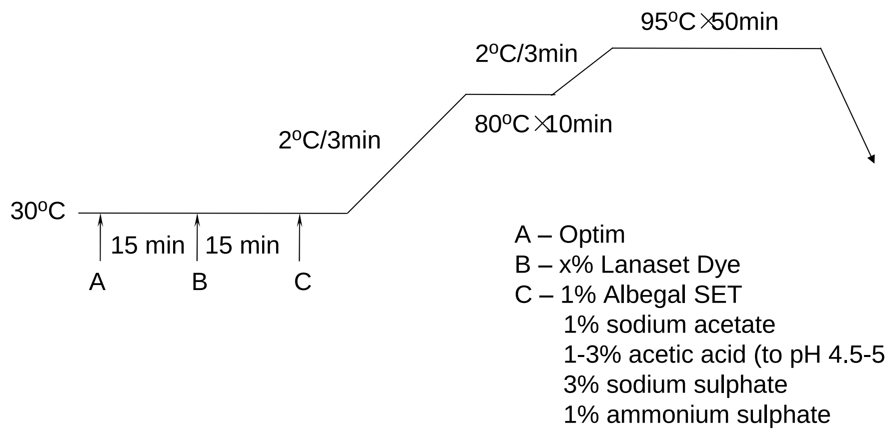

Figure 3 A dyeing method for Optim Fine using Lanaset dyes

In top, and package dyeing of Optim Fine, special precautions need to be taken both in package preparation and machine operation if unlevel results are to be avoided. The reason for this is associated with a marked decrease in the modulus of the wet Optim Fine fibre as the temperature of the dyebath is increased (see Powerpoint slide). [Wool's Space Age Response, Optim^{TM} fine and Optim^{TM} max, A.Y. Bhoyro et al, *Proc. Textile Institute 81st World Conference,* Melbourne, Australia, (April 2001).]

The progressive decrease in fibre stiffness with increasing temperature can result in severe problems in dyeing. Packages can collapse on the dyeing spindles so that dye liquor flows around, rather than through, the packages, and this results in grossly unlevel dyeing. In piece dyeing, stretching and vigorous mechanical action must be avoided at all costs to prevent the fabric from becoming permanently distorted.

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

Some modest improvements have recently been made in the bleaching of wool. The best available technology at present for producing a bleached white on wool and chlorine/Hercosett wool is with a two-step oxidative/reductive procedure using hydrogen peroxide stabilised with Tinoclarite WO (as recommended by Woolmark) for the oxidation step, followed by the ColorClear reduction treatment (Rohm and Haas).

Peroxide bleaching with hydrogen peroxide and Tinoclarite WO:

- 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.

Reduction bleaching by the ColorClear Method (Rohm and Haas) which uses stabilized sodium borohydride, ($NaBH_4$):

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

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

7. Innovations in improving the lightfastness of dyeings

The lightfastness of coloured wool leaves a lot to be desired. Dark shades with good lightfastness can be obtained, but medium and pale depths present problems, particularly in pale and bright shades.

- 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.

The discovery of a special type of UV absorbing agent with affinity for wool has made it possible to improve the lightfastness of dyeings on wool. This product has found applications for upholstery and carpet products. The compound was discovered by workers at CSIRO Division of Protein Chemistry and is marketed as Cibafast W by Ciba. Its structure is shown in Figure 4.

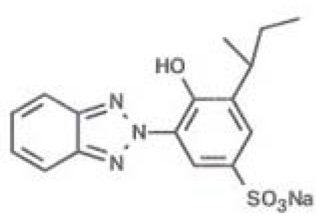

Figure 4 The photoprotective agent Cibafast W

This compound absorbs UV light at wavelengths in the region 290-320 nm that are most damaging to wool. The compound is miscible with water, non-foaming and stable; it may be applied together with dyes in dyeing processes. Very good exhaustion and even uptake is obtained under normal dyeing conditions for wool.

Recommended methods of application are as follows:

- 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.

The light fastness of dyeings with selected metal complex and acid dyes in dark and pale shades is improved and fibre damage on prolonged exposure at high ambient temperatures is reduced. Also the rate of yellowing of unbleached and bleached wool is reduced.

The following results were obtained in trials of the compound. There was 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 depended on the dye and the initial yellowness of the wool. After 50,000 Langleys exposure under glass to sunlight, the yellowness index (YI) of wool was reduced from 17.0 for untreated wool to 12.5 for wool treated with 2% Cibafast W; and the tear strength of the samples increased from 18% to 38% of the untreated value, respectively. [Mosimann et al., *Proc. 8th Int. Wool Text. Conf. Christchurch*, **IV** (1990) 239.]

Australian Wool Innovation started The Pure Bright Wool Program in 2001 to promote research on permanent bright whites and pastel shades on wool fabrics. It is hoped that the development of stable whites and bright coloureds will enable wool to regain market share in leisure, baby and kids wear which has been lost over the last 30 years.

8. Innovations in digital printing technology

Printing of wool fabrics is a costly process, especially for short runs. It is not surprising, therefore, that currently only about 1% of wool fabric is printed. Screen printing has been the method of choice for printing on wool fabrics. However, major costs are incurred in setting up screens and equipment for this printing method and this has limited printing on wool because the long runs required to recoup set-up costs are not generally available. Additional costs are incurred in printing wool because the fibre must be pre-treated, prints need to be fixed by steaming under saturated conditions, and the fabric must be washed off and dried. All these factors conspire to confine printed wool to products to low volume, high fashion, sectors of the market. However, very recently the situation has changed because of the availability of new technology. Digital ink jet printing technology has recently made great strides in reducing cost and increasing productivity in printing short runs of fabric. Wool is uniquely positioned to benefit from this technology.

Digital printing uses a computer to control a series of ink-jets in a printing head that traverses across the fabric while it moves forward underneath the printing heads. Patterns are made and transmitted as electronic data, using Computer-Aided Design (CAD) systems. Patterns can be loaded, modified and duplicated swiftly and easily and rapidly downloaded to printing machines.

Ink-jets for fabric generally operate using two technologies, drop-on-demand (usually with piezo heads) and continuous ink-jet. At present, piezo jets appear to be offer the best technology for high resolution printing. Resolutions of greater than 600 dots per inch are obtainable. This makes photographic quality prints on suitable fabrics a reality.

Most major dye makers are now able to 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 are fixed using methods appropriate for the fibre and type of colourant.

In the case of wool, best results may be obtained with inks formulated using conventional milling, premetalised and reactive dyes on pretreated fabric (chlorinated or equivalent). Available inks include Lanaset RAC for the DReAM machine and Lanaset SI-HS (Ciba) and Artistri Inks (Dupont). After printing, the prints are fixed by steaming; then the fabric is washed off, as with other direct printing methods for wool.

One of the market leading fabric printing machines is the Reggiani DReAM digital printer. It can print fabrics up to 1,800 mm wide in 8 colours with 16 drop-on-demand piezo print heads with resolution from 360 to 720 dots per inch and speeds from 66 sq m per hour to 11 sq m per hour. The low production speed of this type of machine must be offset against the cost and time taken in setting up conventional printing equipment to print only a few pieces of fabric.

Recently, small printing, steaming and washing off units have become available. These are based on machines developed by Stork. They should be well suited to printing exclusive designs on shorter lengths of fabric. A coupled printer and steamer from Rimslow (Stork) is shown in Figure 5.

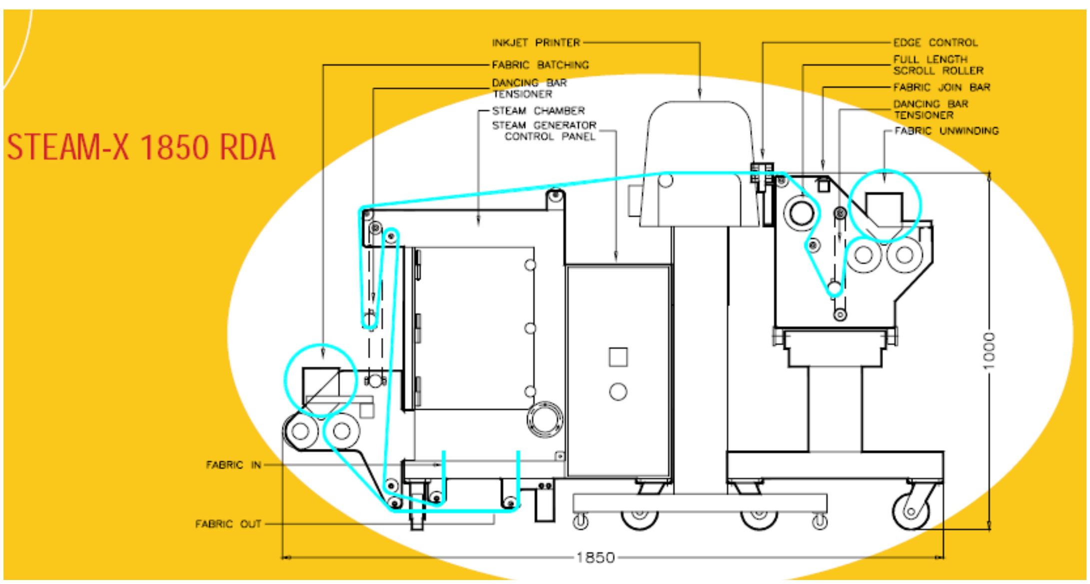

Figure 5 A coupled digital printer and steamer marketed by Rimslow.

9. Innovations in future

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

The last half centuary has seen wool changing from a commodity textile fibre into a specialty niche fibre, as its share of the textile market has steadily declined. This has been inevitable because it has not been possible to reduce the relatively high cost of production, nor has it been possible to drastically modify the fibre, because of limitations in morphology (mostly diameter) and in chemistry, and these restrictions arise from the fact that the fibre is grown by an animal.

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 to some extent.

In the current situation, wool's loss of market share has made it inevitable that many technical innovations will occur as a result of spin-off from developments for other textile fibres. Recent history has shown that when wool-specific innovations have occurred, they have been generated by research financed from levies on wool production, principally within Australia.

Questions for review and further study

1. How could electronic systems be used to eliminate visual inspection of colours in the dyehouse?
2. Which factors in production would need to be controlled to qualify for Eco labeling?
3. How would automation be best introduced to a dyeing factory currently using equipment exclusively under manual control?
4. What factors are crucial to improving the quality of dyed goods?
5. In order to examine the feasibility to produce goods dyed to pale depths with the best available lightfastness, what R&D and product development steps would be required?
6. What are the critical technical factors to be considered to set up a profitable, low volume, wool printing business?