Control in the laboratory and the dyehouse

Contemporary wool dyeing and finishing

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Summary

1. 'Right first time' dyeing.
2. The parameters which must be measured and controlled for reproducibility in dyeing.
3. pH and wool dyeing:
    - the importance of pH
    - measurement of pH
    - control of pH.
4. Automatic operation of dyeing machines.
5. Automatic dye and chemical dispensing.
6. The automated dyehouse.
7. Special dyeing methods:
    - cold pad batch
    - optim fine
    - ombré.

1. 'Right first time' dyeing

‘Right first time’ dyeing

- Dyeing has traditionally been more art than science.
- About 5 to 15 percent of a typical plant’s production has to be re-dyed or discounted because colours didn’t come out right the first time.
- Incorrectly dyed fabric can cost a textile dyeing plant between $1.5 million to $5 million annually.
- Progress can only be made towards “right first time” by:
  - ensuring consistency in raw materials (preparation, dyes, auxiliaries, water)
  - selection of appropriate dyes and dyeing methods
  - accurate weighing and regain control
  - control of **all** the operating parameters
  - eliminating human error during processing.

2. The parameters which must be measured and controlled for reproducibility in dyeing

The following parameters must be measured and controlled for reproducibility in dyeing:

- pH
- temperature
- flow rate and direction
- additives
- dye exhaustion.

- Of these, only dye exhaustion monitoring has not been reliably achieved, despite a large amount of effort during the last 20 years. New companies are continually being set up (e.g. HueMetrix in the USA, 2005).

3. pH and wool dyeing

The importance of pH

Why is pH important in processing wool?

- Control of pH is essential for reproducibility in many dyeing and finishing processes.

- pH can critically affect the following processes in dyeing and finishing:
  - dyeing kinetics and equilibrium with charged dyes and charged fibres
  - reaction of reactive dyes
  - colour stability of disperse dyes (in dyeing blends)
  - chemical damage to wool, silk and nylon
  - permanent setting of wool.

Dyeing and pH

- With charged dyes and charged fibres (e.g. anionic dyes on wool and nylon, cationic dyes on acrylic and basic dyable nylon), pH affects:
  - dyeing rate
  - levellness
  - dye affinity.

- The net charge on the wool fibre depends on the pH and can be varied from strongly positive to slightly negative. Since most wool dyes carry a negative charge, the ionic contribution to dye affinity can be made greater or less by fixing the pH.

Changes to groups in wool with pH

Functional groups:

$W\text{-}COOH$ Û $W\text{-}COO^-$ + H^+ e.g. pK_a of aspartic acid = 3.92

$W\text{-}NH_2$ + H^+ Û $W\text{-}NH_3^+$ e.g. pK_a of glycine = 9.91

pH	Functional Groups	Net Charge on Fibre	Dyeing Type
2.0	$W\text{-}COOH$, $W\text{-}NH_3^+$	Strongly positive	Acid, 1:1 premetallized
3.5	$W\text{-}COOH$, $W\text{-}COO^-$, $W\text{-}NH_3^+$	Positive	Weak acid
4.7	$W\text{-}COOH$, $W\text{-}COO^-$, $W\text{-}NH_3^+$	Zero	Milling, 1:2 premetallized
7.0	$W\text{-}COO^-$, $W\text{-}NH_3^+$	Negative	1:2 premetallized
12	$W\text{-}COO^-$, $W\text{-}NH_2$	Strongly negative	Washing off

The pH is often raised towards the end of a dyeing to increase exhaustion and control levellness of anionic dyes, by increasing the net positive charge on the fibre.

Fixation of reactive dyes

On cotton and polyamides (including wool)

neucleophilic substitution and addition reactions are both base catalysed:

$$\text{Fibre-BH} + \text{Dye-X} \;?\; \text{Fibre-B-Dye} + H^{+} + X^{-}$$

$$\text{Fibre-BH} + \text{Dye-CH}{=}CH_2 \;?\; \text{Fibre-B-}CH_2\text{-}CH_2\text{-Dye}$$

$-BH = -NH_2$, OH, etc. $X = F$, Cl, etc.

In polyamides such as wool, the concentration of reactive $-NH_2$ groups depends on the pH

$$PA\text{-}NH_2 + H^{+} \Leftrightarrow PA\text{-}NH_3^{+}$$

pH is often raised (by addition of a base or a pH sliding compound) after exhaustion and levelling to increase the extent of reaction with the fibre.

Hydrolysis of reactive dyes

Reactive dyes react with water as well as with fibres, for example:

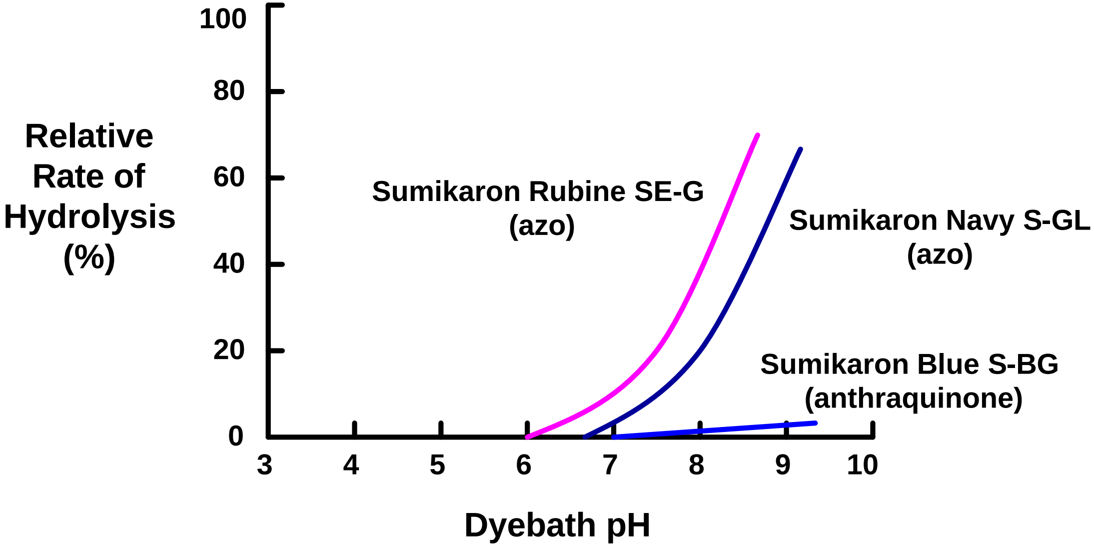
$$\text{Dye} – \text{X} + \text{H.OH} \ ? \ \text{Dye} – \text{OH} + \text{H}^{+} + \text{X}^{-}$$

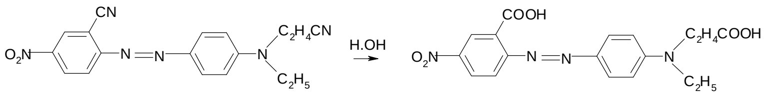
Too much hydrolysed dye leads to poor colour yields and low fastness.

Particularly when dyeing cotton, alkali should be added as late as possible in the dyeing process and never to stock solutions unless they are to be used immediately.

Colour stability of disperse dyes

Disperse dyes on polyester and nylon are usually dyed at pH 4 – 5 to avoid hydrolysis of substituent groups and to obtain optimum colour stability and substantivity.

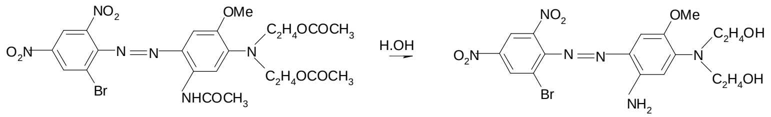




good affinity

hue change

poor affinity



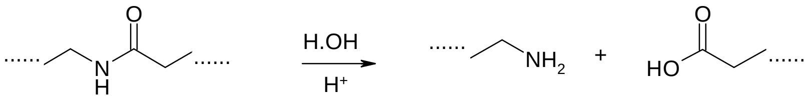
good affinity

hue change

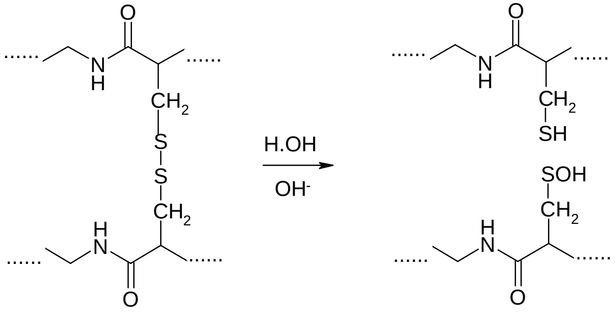
poor affinity

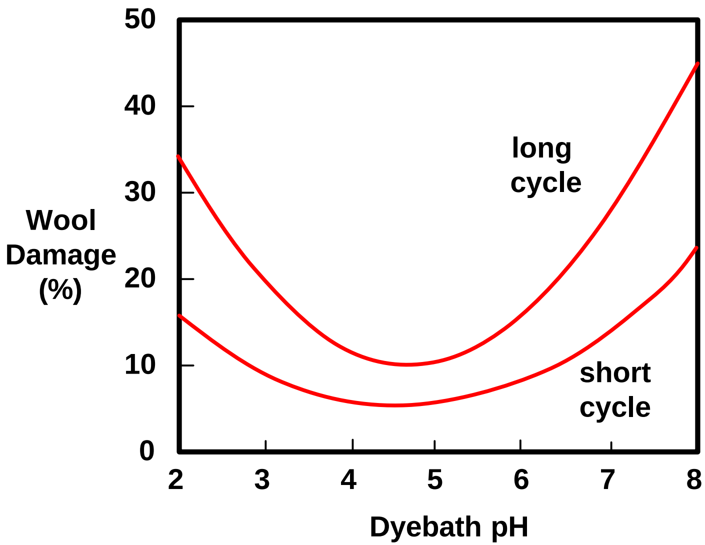
Damage during dyeing of wool

Amide bond hydrolysis



Disulphide bond hydrolysis of wool





Damage to wool occurs at both low and high pH.

From: “Damage in wool dyeing”, D M Lewis, *Rev. Prog. Color*., **19** (1989) 49.

Damage to wool during dyeing

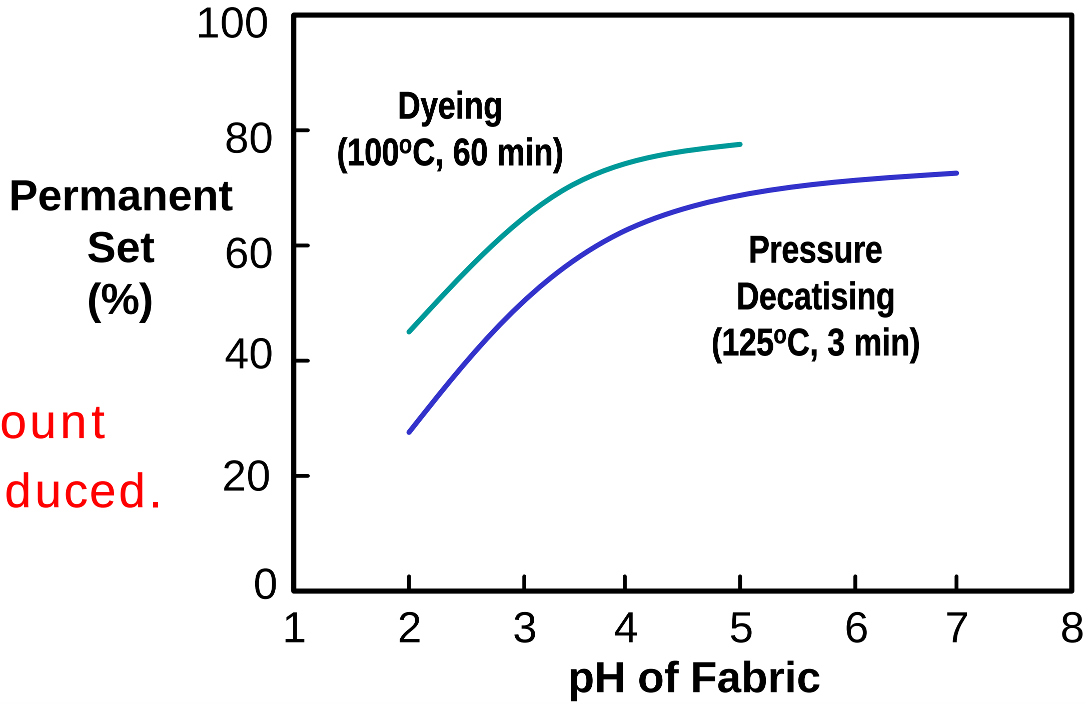
The result is:

- lower fibre strength
    - increased waste in carding and combing (noil)
    - more fly in spinning
    - increased ends down during spinning
- reduced yarn strength
    - more yarn breaks during warping and weaving
- decreased abrasion resistance and tear strength of fabric.

Permanent setting of wool

These processes introduce permanent set into wool:

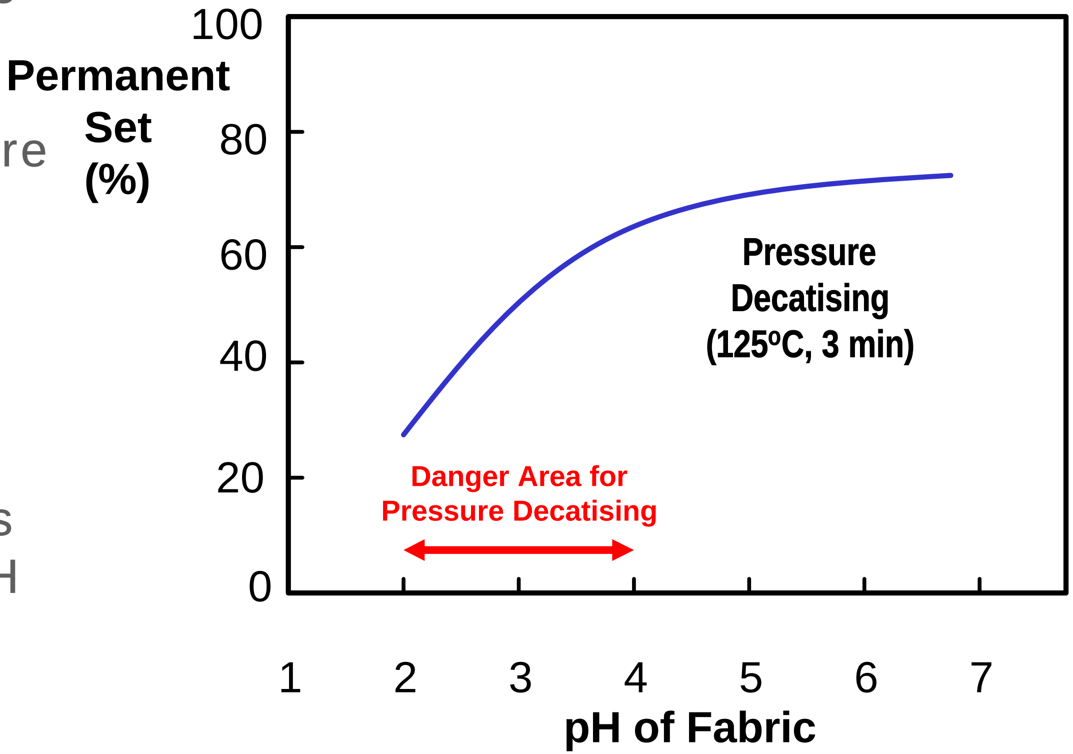
- crabbing
- pressure decatising
- wet decatising
- chemical setting
- dyeing.



pH determines the amount of permanent set introduced.

Pressure decatising of wool

- Fabric left in an acid condition after dyeing will have little permanent set introduced by pressure decatising.
- Pressure decatising then has only a temporary pressing effect.
- Pressure decatising is best carried out at pH 5-7.



Definition and measurement of pH

$$pH = -\log_{10}[H^+]$$

the hydrogen ion is hydrated as H_3O^+
but it is often written as H^+

$[H^+]$	10^{-1}	10^{-3}	10^{-5}	10^{-7}	10^{-9}	10^{-11}	10^{-13}	moles/litre
pH	1	3	5	7	9	11	13	
		Acidic		Neutral		Basic		

pH in aqueous solutions

Ionization of water $H_2O \Leftrightarrow OH? + H^+$

$$K_a' = [OH?]\ [H^+]\ /\ [H_2O]$$

since $[H_2O]$ = constant = 55.5 moles/litre

$$K_w = [OH?]\ [H^+]$$

And pKw = pOH + pH

Temperature (ºC)	**K_w**	**Neutral pH**
24	**1.0×10^{-14}**	**7.0**
60	**1.0×10^{-13}**	**6.5**
100	**5.5×10^{-13}**	**6.1**

Measurement of pH

pH measurement

$$E_{pH} = E_{constant} + 2.3\ R\ T\ /\ n\ F\ \log a_{H}$$

$$a_{H+} = ?\ [H^{+}]$$

$$pH = -\log_{10}[H^{+}]$$

where:

? = activity coefficient of the hydrogen ions, usually assumed = 1 (OK for dilute solutions)

E_{pH} = voltage difference between the electrodes

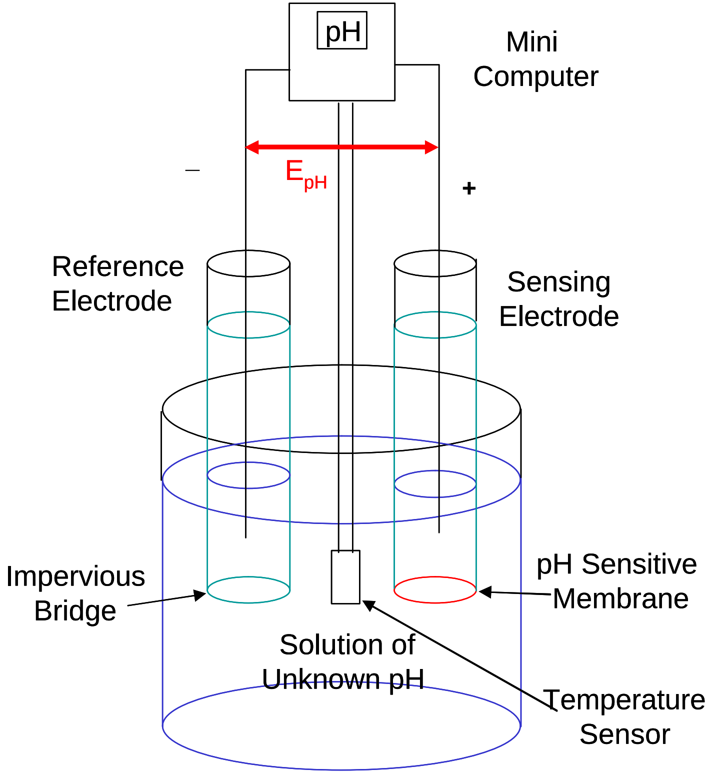
$E_{constant}$ = voltage of reference electrode

R = Gas constant (8.314 J K^{-1} $mole^{-1}$)

T = temperature in degrees Kelvin

n = valency per ion (1 for H^{+})

F = Faraday's constant (96500 C $mole^{-1}$)



Meters measure the **activity** of hydrogen ions in solution - **not the concentration.**

A pH meter for the laboratory

- A pH meter consists of:
    - an electrode to sense pH
    - a reference electrode
    - a temperature sensor
    - an electronic calculator and readout module.
- Usually the electrodes and temperature sensor are packaged into a "combination electrode" which is more convenient to use.
- The meter must be frequently calibrated with buffer solutions.

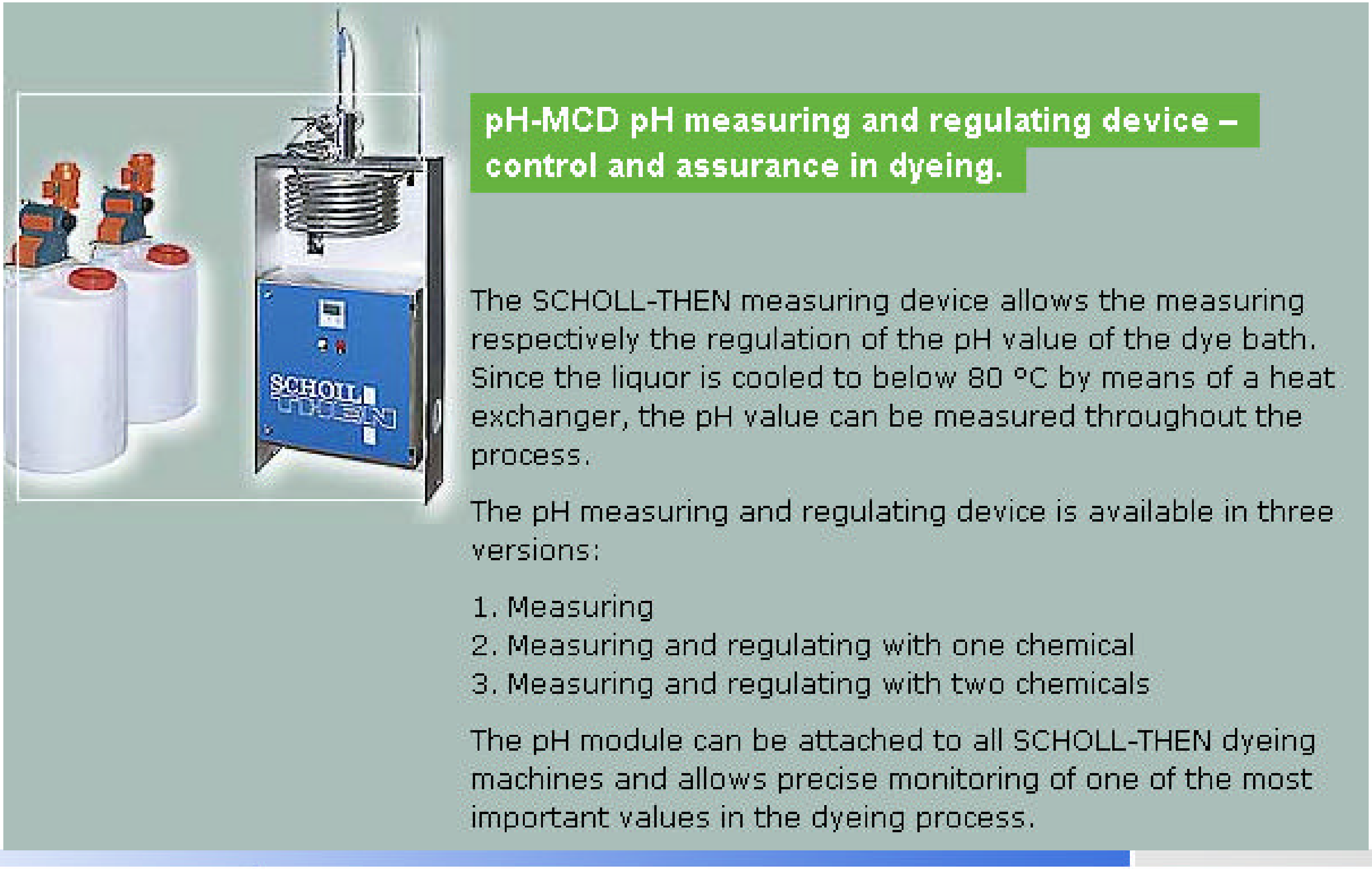
Measurement of pH in industry

Requirements for industrial pH measurement:

- robust technology with low maintenance
- user-friendliness
- automatic calibration
- long-lasting electrodes
- simple connection to industrial liquid streams
- outputs for machine control computers.

OBEM pH measurement

pH measurement in dye liquors



pH-MCD pH measuring and regulating device – control and assurance in dyeing.

The SCHOLL-THEN measuring device allows the measuring respectively the regulation of the pH value of the dye bath. Since the liquor is cooled to below 80 °C by means of a heat exchanger, the pH value can be measured throughout the process.

The pH measuring and regulating device is available in three versions:

1. Measuring
2. Measuring and regulating with one chemical
3. Measuring and regulating with two chemicals

The pH module can be attached to all SCHOLL-THEN dyeing machines and allows precise monitoring of one of the most important values in the dyeing process.

pH-FiT for pH measurement during dyeing

- Fuzzy-integrated-Technology pH measurement and regulating system for pH controlled dyeing.
- Fully automated calibration of the probes.
- Stationary or mobile.
- Re-cooler.
- Developed by DyStar, SETEX and Thies.

Control of pH

The best ways to control pH in dyeing

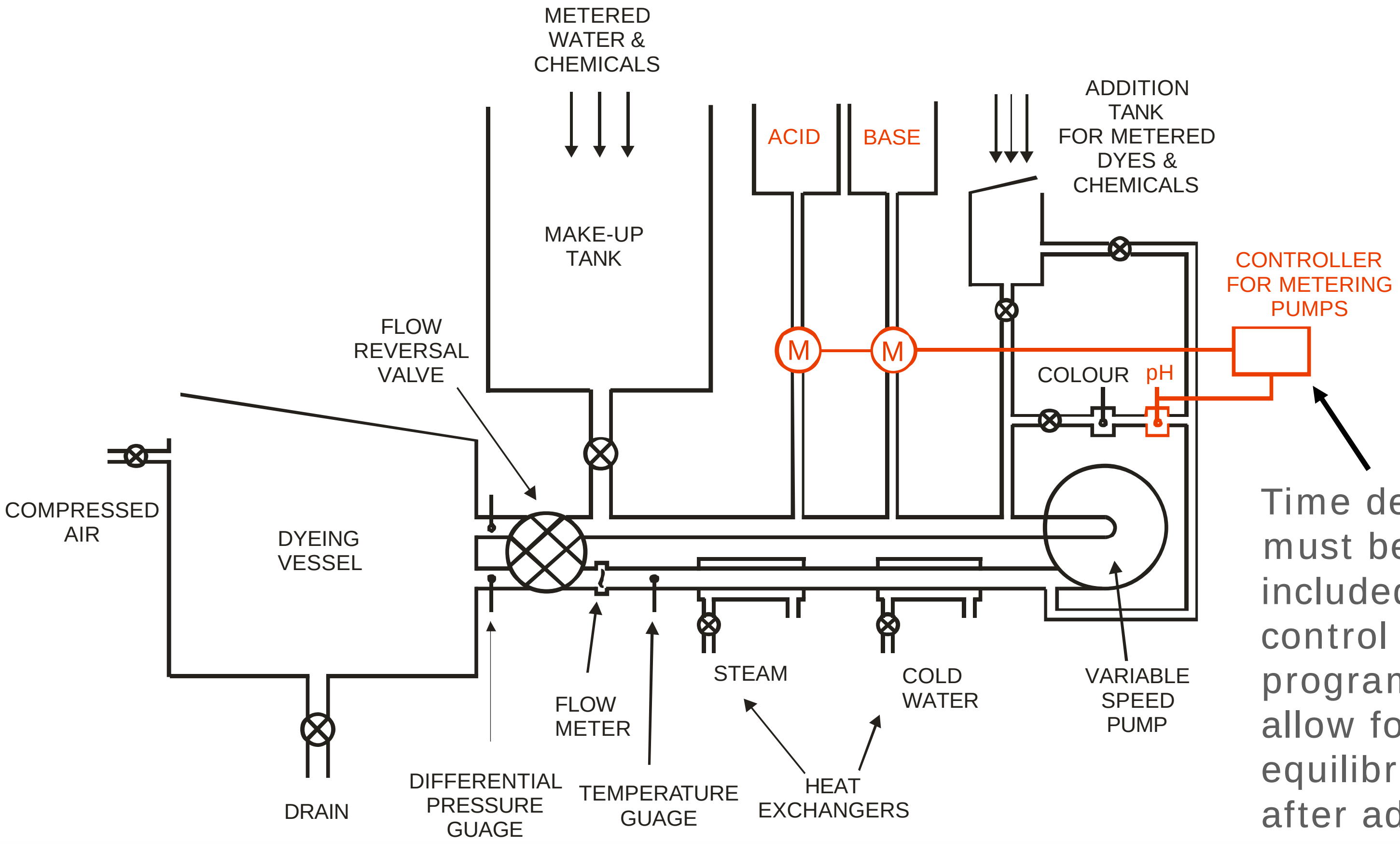
To keep pH under control during wet processes, and to avoid problems with carry-over of acid or base from previous processes:

- use buffer solutions for constant pH
- use hydrolysable compounds to change pH
- dose strong acid or base automatically with pH sensing to keep pH constant or to change it.

Reasons for changing pH during dyeing

- To increase dye exhaustion, by lowering the pH:
  - can be used with anionic dyes and fibres with end groups that can be protonated, e.g. wool and nylon.
- To promote reaction between dye and fibre, by raising the pH:
  - can be used with any reactive dyes which undergo base catalysed reactions, e.g. reactive dyes on cellulosics and wool.
- To decrease damage to wool when dyeing with 1:1 premetallised dyes, by raising the pH:
  - replace sulphuric acid with sulphamic acid.

Automatic control of pH by dosing strong acid and base



Time delay must be included in control program to allow for equilibration after additions.

Buffer solutions for constant pH

Acid / base equilibrium in water

acid Û base? + H^+

HA Û A? + H^+

HA and A? are called a **conjugate acid** and **conjugate base** respectively. They must be weak acids or bases, i.e. not completely dissociated into ions.

e.g. CH_3COOH Û CH_3COO? + H^+

Dissociation constant

$$K_a = a_{A-} \, . \, a_{H+} \, / \, a_{HA}$$

a_i = activity of the species i = ?$_i$. $[X_i]$

where ?$_i$ = activity coefficient, (usually assumed = 1) and $[X_i]$ is the molar concentration

Apparent dissociation constant

K_a' = [A?] $[H^+]$ / [HA] (1)

and $pK_a' = -\log_{10}[K_a']$

Buffer solutions for constant pH

By rearranging equation (1) we obtain the pH of a buffer solution:

$$pH = pK_a' + \log_{10} [A?] / [HA]$$

(Henderson-Hasselbach Equation).

- The main advantage of a buffer is that it resists changes in pH.
- The best stabilisation of pH is when pH = $pK_a \pm 1$, i.e. when the buffer solution contains similar concentrations of conjugate acid and base.

Not buffers – sodium sulphate (and sulphuric acid)
– ammonium sulphate.

pKa values of buffers when [acid] = [base]

These buffers are commonly used in textile processing.

They can be used to control pH within ± 1 unit of their pK_a values.

Buffer	pK_a of conjugate acid at 20^{o}C
H_3PO_4 / NaH_2PO_4	2.12
Formic acid / Na formate	3.75
Lactic acid / Na lactate	3.86
Acetic acid / Na acetate	4.76
Na_2 H citrate / Na_3 citrate	5.40
NaH_2PO_4 / Na_2HPO_4	7.22
NH_4SO_4 / NH_3	9.40
$NaHCO_3$ / Na_2CO_3	10.25
Na_2HPO_4 / Na_3PO_4	12.67

Some commercial buffer solutions

- Cibatex AB-45 pH for PES and W.
- Sandacid HAI, PBI (+ acetic acid buffer for disperse dyes).

Causes of unintentional changes in pH

- Acid or base on fibre from inadequate neutralisation after carbonising or scouring respectively.
- Contaminated water supply.
- Open dyeing machines (volatile acid or base can be lost).
- Insufficient buffering (concentration too low).

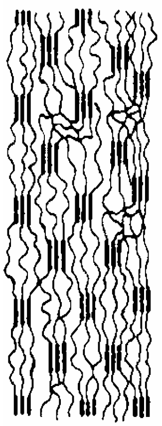
Problem buffers

  - acetic acid / acetate
  - formic acid / formate
  - ammonia / ammonium salt
- Because acetic acid, formic acid and ammonia are volatile, the above buffers will not keep the pH constant in open dyeing machines.
- When dyeing wool, buffers with aromatic anions (phthalate, etc.) should not be used because they may compete with dye anions for absorption sites and lower dye absorption.

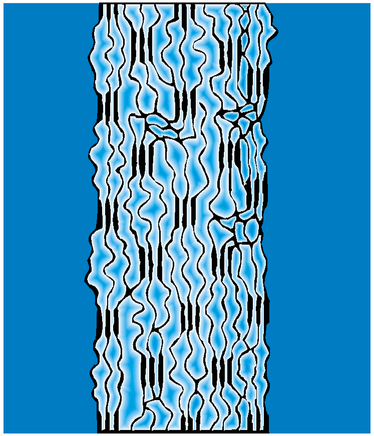
Is the pH in solution the same as in the textile fibre?

Some fibres (e.g. polyamides, cellulosics) swell considerably when they are dyed in water:

Dry fibre



Fibre swollen with water



Is the pH in the water inside the fibre (pHout) the same as in the water inside the fibre (pH$_{in}$)?

$pH_{outside}$ may not be = pH_{inside}

- When the fibre:
  - is swollen with water and
  - contains charged groups which can not move out of the fibre (wool, silk, nylon including deep and basic dyeable types etc.)
  - when ionic strength is low (<0.05 M).

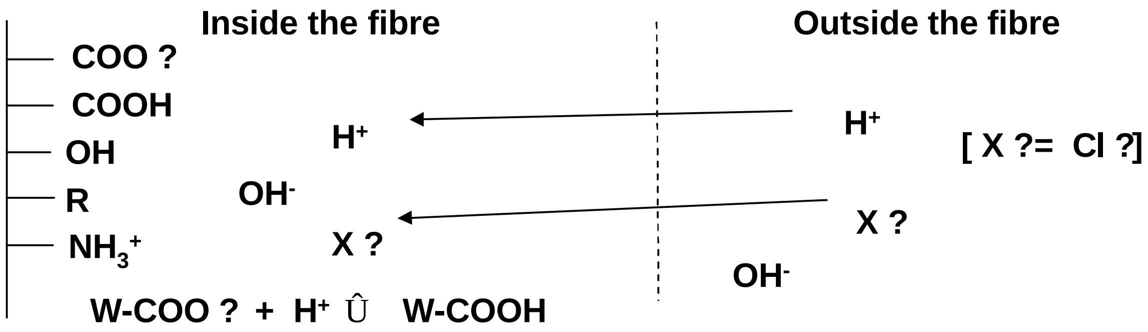
- No problem with cellulosics because fibres do not contain charged groups.

When $pH_{outside}$ may not be = pH_{inside}

- Activity of water inside the fibre may be different form the bulk phase because much of the internal water may be “hindered” by hydration of ionic groups, hydrogen bonding with polar groups, and structuring near hydrophobic groups.
- Concentrations of dissolved substances may be higher than expected.
- Activities of ions may be lower than in the external phase.
- There may be competition between ionic sites and mobile ions for solvation by water molecules.

Donnan membrane equilibrium

When clean wool in the isoelectric state is placed in a strong acid solution:



Inside the fibre

Outside the fibre

COO ?

COOH

OH

R

NH_3^+

H^+

OH^-

X ?

H^+

X ?

OH^-

[X ?= Cl ?]

W-COO ? + H^+ Û W-COOH

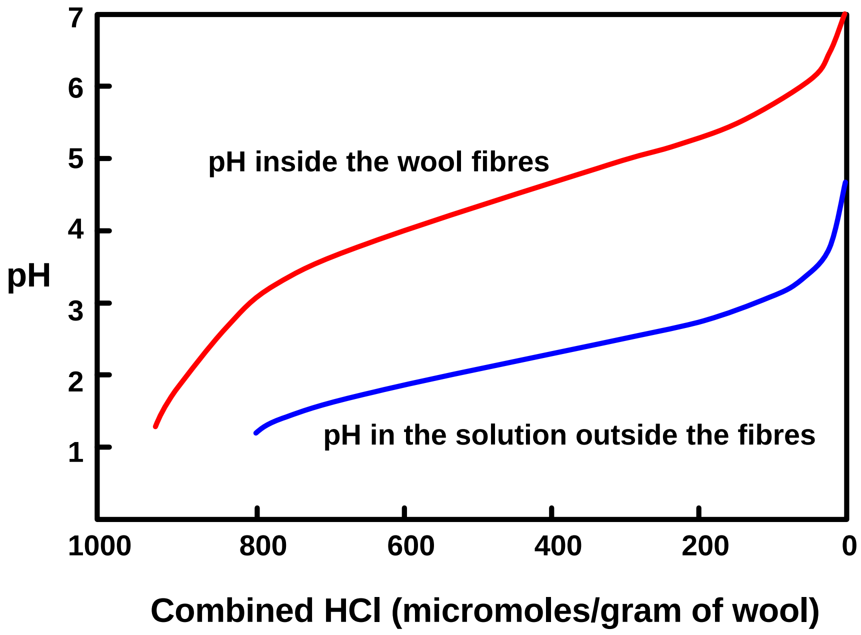
- Charged groups inside the fibre can not move out.
- Ions can only move in.
- Electrical neutrality must be maintained inside and outside the fibre.
- Donnan equilibrium must be satisfied, i.e. $[H_{in}^{+}]/[H_{out}^{+}] = [X_{out}^{-}]/[X_{in}^{-}]$

  Result – The pH inside the fibre can be up to 2 units different from the outside pH.

Calculated internal pH of wool

In strong acid solution at low ionic strength (no added salt).

The pH inside the fibre can be 2 units greater than the pH in the external solution.

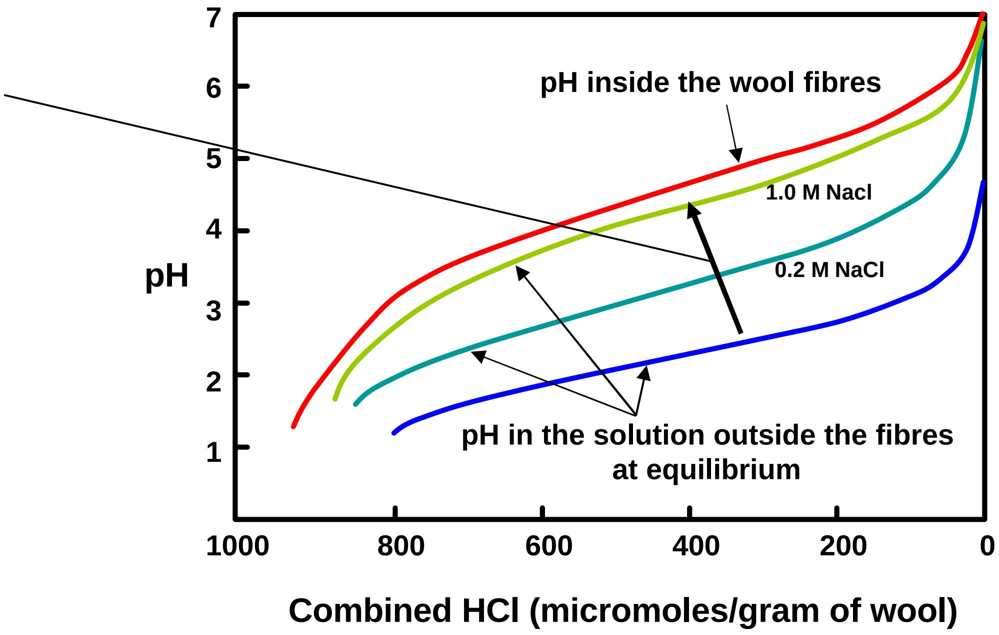


From: L Peters and J B Speakman, "Combination of wool with acids" *J.S.D.C.*, **65** (1949) 63.

Calculated internal pH of wool

The effect of increasing the salt concentration (ionic strength).

The pH inside the fibre approaches that of the external solution.



From: L Peters and J B Speakman, “Combination of wool with acids” *J.S.D.C.*, **65** (1949) 63.

Effect of salt on the pH of solutions containing wool

pH values of solutions

	No Wool	Wool	Wool + 0.02 M NaCl	Wool + 0.06 M NaCl	Wool + 0.2 M NaCl	Wool + 1.0 M NaCl
1.5% owf HCl	2.0	2.3	2.6	2.7	2.8	2.8
2.4% owf acetic acid	3.4	3.6	4.3	4.3	4.4	4.4
2.4% owf acetic acid + 3.3% owf Na acetate	4.5	4.7	4.8	4.8	4.8	4.8

Uptake of acid by the wool does not reach a maximum until the internal and external pHs are about the same,
This does not happen until the ionic strength is at least around 0.05M.

Use of salt in dyeing wool

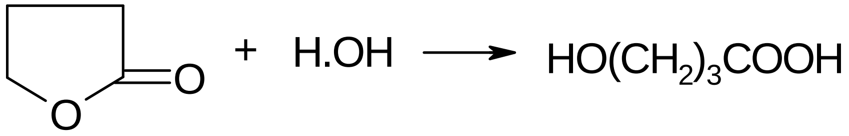
- Up to 10% (owf) of sodium sulphate is often added to dyebaths to reduce the rate of uptake of dyes by electrostatic ‘screening’ of the charged fibre surface and by competition between sulphate ions with dye anions absorption sites.
- Ammonium sulphate is also sometimes used, particularly at higher pHs.
- The presence of these salts raises the ionic strength in the dyebath and helps to equalise the pH inside and outside the fibre.

10% (owf) Na_2SO_4 at a LR of 40:1 gives I = 0.08M

3% (owf) $(NH4)_2SO_4$ at a LR of 40:1 gives I = 0.02M

pH control with a hydrolysable ester

- Sandacid VS (γ-butyrolactone) gives a change from pH 7 to pH 4.5.



$$HO(CH_2)_3COOH \Leftrightarrow HO(CH_2)_3COO? + H^+$$

Hydrolysis of γ-butyrolactone produces hydroxybutyric acid.

- Sandacid VS + sodium carbonate gives a change from pH 9 to pH 5.5.

$$CO_3{}^{2}? + H^+ \Leftrightarrow HCO_3? \; pK_a = 10.38$$

$$HCO_3? + H^+ \Leftrightarrow H_2CO_3 \quad pK_a = 6.38$$

- Other hydrolysable esters e.g. 2-hydroxyethyl chloroacetate have been used, but these are rather toxic.

Dyeing 1:1 premetallised dyes

- The advantage of replacing sulphuric acid with sulphamic acid is that the pH will rise when the boil is reached due to the following hydrolysis reaction:

$$H_2N\text{-}SO_3H \;+\; H_2O \longrightarrow NH_4^+ \;+\; HSO_4^-$$

sulphamic acid ammonium bisulphate

- The pH of this system changes from 1.8 to 3.5 from start to finish of the dyeing operation, thereby reducing the overall fibre damaging effect of the procedure.

Summary of the importance of pH in dyeing

- pH is important in several critical processes in dyeing and finishing.
- pH can be best controlled by use of buffer solutions, hydrolysable compounds or automatic dosing systems.
- With wool and other polyamides, enough salt must be present to ensure that the pH inside the fibre is the same as in the external solution.
- pH adjustment before dry finishing should help with reproducibility of pressure decatising.

4. Automatic operation of dyeing machines

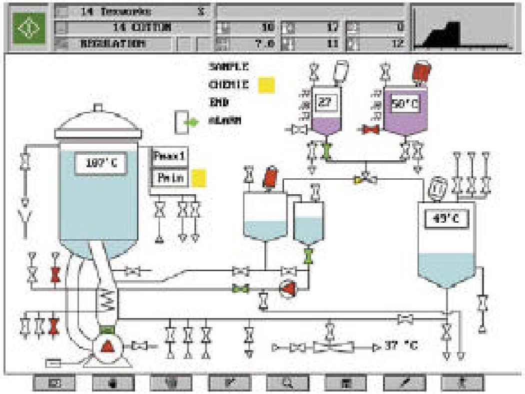
Automatic operation of dyeing machines

- For minimum control of a dyeing machine, the following functions are required:
  - machine filling (by an actuated valve and level sensor)
  - raising to the initial temperature at a rapid rate (by an actuated steam valve and temperature sensor)
  - circulation rate (either of material or liquor or both)
  - raising of temperature at an accurately controlled rate
  - flow reversal as required
  - holding time at a set temperature
  - cooling at a controlled rate (preferably via a heat exchanger
  - draining (actuated valve).

Automatic operation of dyeing machines

Baco Sedomat 5000 universal controller

- Can be used stand-alone with all batch dyeing machines such as cabinets, jets, jiggers and winches to control temperature, time, speed, flow rate, differential pressure, pH, circulation control and dosing.
- Barcode reader for lot identification.
- Can be linked with a fully automatic dye kitchen for the preparation of dyestuff and chemicals.
- Can also control finishing machines for singeing, bleaching, mercerising, washing, drying, continuous dyeing, stenters, shrinking, decatisers, calenders, raising and emerising.
- Easily integrated into a total computer implemented management concept.



Automatic operation of dyeing machines

OBEM touch-screen dyeing machine controller

- The VisualDye Controller is on Windows™ system, and based on industrial PC with a Color Touch Screen display. It is possible to control all the functions of the machine in manual or automatic modes.
- Up to 400 dyeing treatment cycles, each one with 200 different steps, can be easily created, started and modified.
- User friendly software ‘guides’ the dyer in programming even very complex cycles and helps him to control all the technological parameters of the machine, by means of several pages of graphical interface which can be recalled by simply touching the display.

DYEING OBEM MACHINERY

Automatic operation of dyeing machines

737 XL Programmable
Micro Processor
Controller

T 737 XL Programable Controller

TEXTILMASCHINEN Thies

5. Automatic dye and chemical dispensing

Automatic dye and chemical dispensing

Liquid Chemical Supply MPS-L

- Volumetric dosing of Liquid Chemicals
- Modular extension 10, 20 ....
- Low level inlet
- Integrated manual dispensing option
- Low maintenance

Liquid Chemicals

TEXTILMASCHINEN Thies

Automatic dye and chemical dispensing

Powder Dyestuff Storage and Dispensing

- Option of varying capacities
  - 20 to 80 products
- Dust Extraction system
- One or more scales
- Automatic product retrieval
- Interface to OrgaTEX

Powder Dyes

Automatic dye and chemical dispensing

Dyestuff dissolving station

MPS-D

CAPACITIES
- 100, 200, 300, 600 litres

OPTIONS :
- Hot water preparation station
- Water blending valve

Powder Dyes

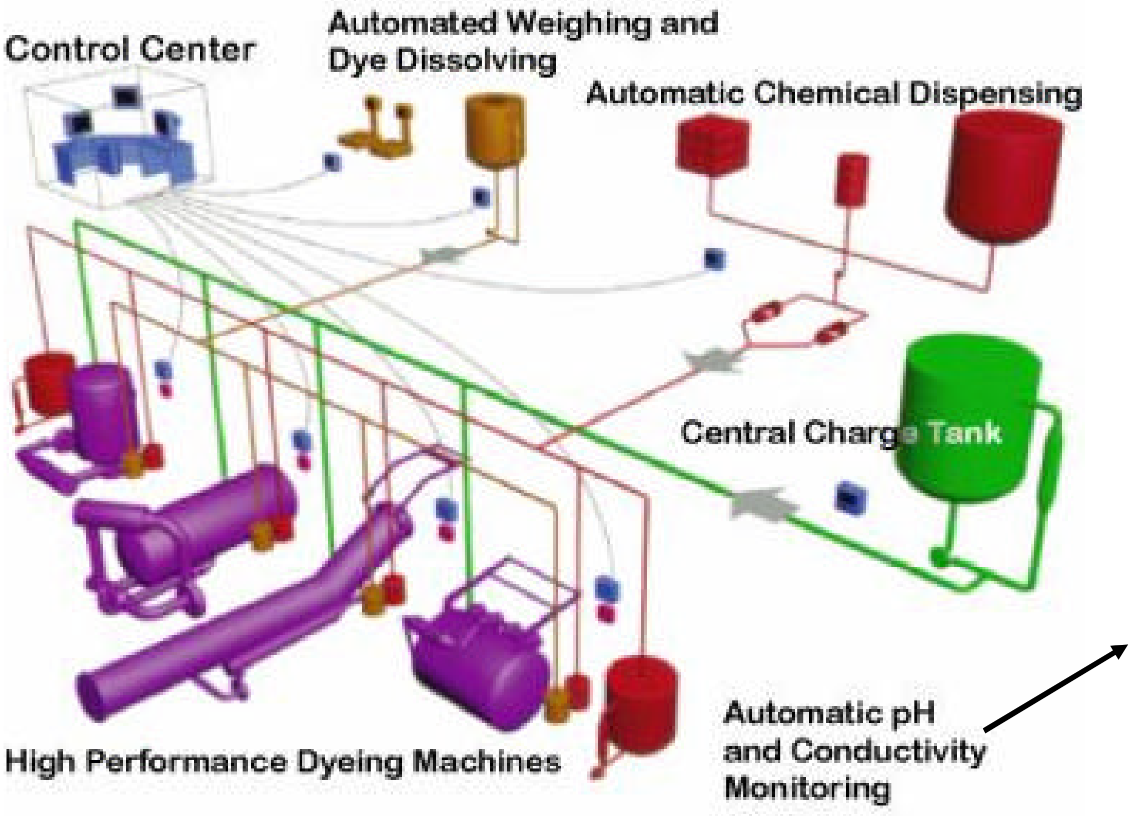
TEXTILMASCHINEN Thies

6. The automated dyehouse

The automated dyehouse

- Various functions can be integrated, depending on the degree of control warranted by the economics of production. Ultimately the whole can be brought together as follows:
    - a piping system needs to be installed to allow dye and chemical solutions to be dispensed automatically to individual machines
    - operation of weighing and dissolving stations, as well as dyeing machines, needs to be programmed, monitored and controlled from a central station
    - production batch planning, dye and chemicals ordering, and dye lot identification can to be integrated into the control system
    - heat recovery and water recycling can also be controlled.
- These types of systems are illustrated in the following slides.

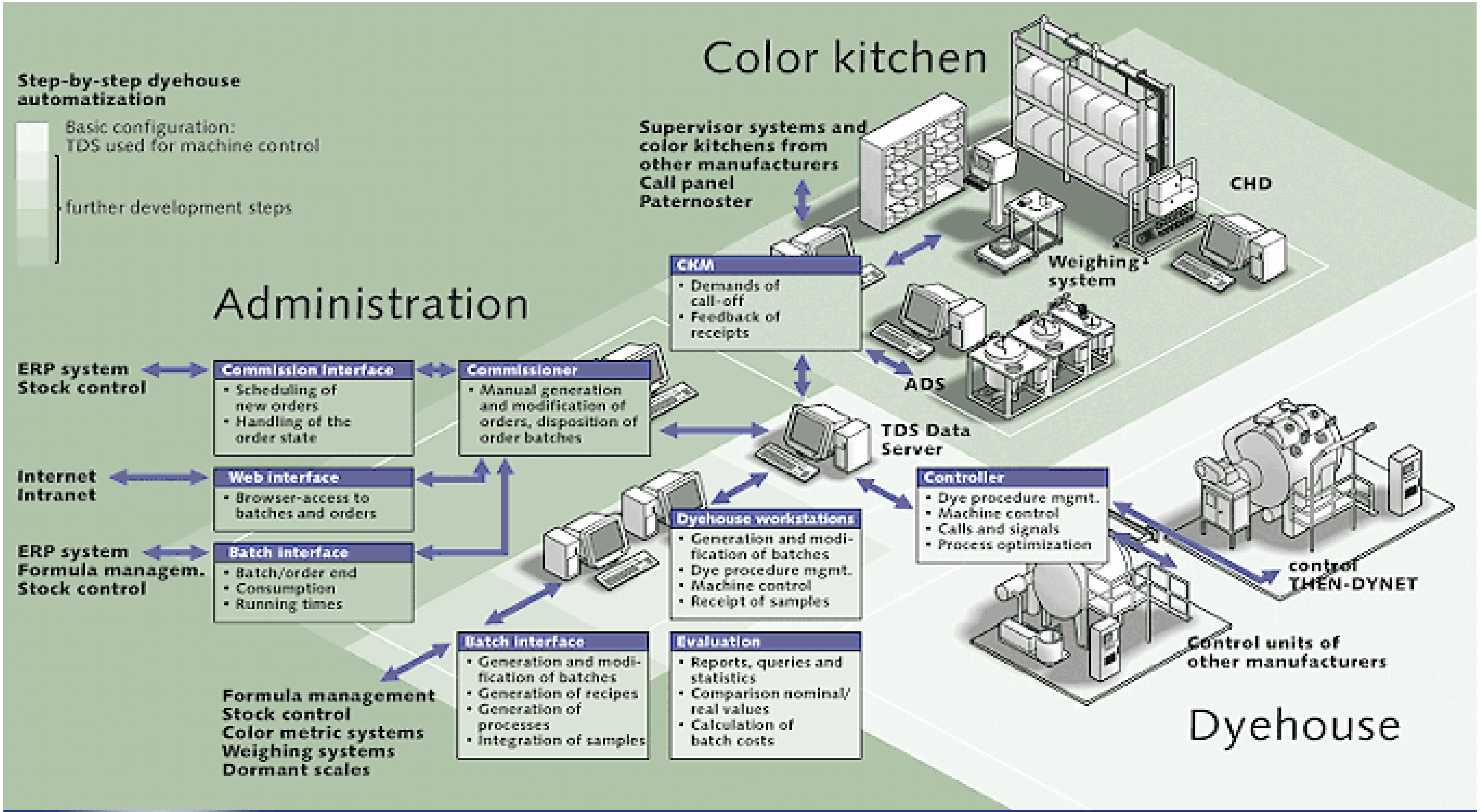
Automatic dyeing system



Gaston County Millennium Dyeing System

This is just one of several commercial systems. Doseacid of Ciba is another.

The Then fully integrated dyehouse



Step-by-step dyehouse automatization

Basic configuration:
TDS used for machine control

further development steps

Color kitchen

Supervisor systems and color kitchens from other manufacturers
Call panel
Paternoster

CHD

Weighing system

ADS

CKM
- Demands of call-off
- Feedback of receipts

TDS Data Server

Administration

ERP system
Stock control

Commission interface
- Scheduling of new orders
- Handling of the order state

Commissioner
- Manual generation and modification of orders, disposition of order batches

Internet
Intranet

Web interface
- Browser-access to batches and orders

ERP system
Formula managem.
Stock control

Batch interface
- Batch/order end
- Consumption
- Running times

Dyehouse workstations
- Generation and modification of batches
- Dye procedure mgmt.
- Machine control
- Receipt of samples

Formula management
Stock control
Color metric systems
Weighing systems
Dormant scales

Batch interface
- Generation and modification of batches
- Generation of recipes
- Generation of processes
- Integration of samples

Evaluation
- Reports, queries and statistics
- Comparison nominal/ real values
- Calculation of batch costs

Controller
- Dye procedure mgmt.
- Machine control
- Calls and signals
- Process optimization

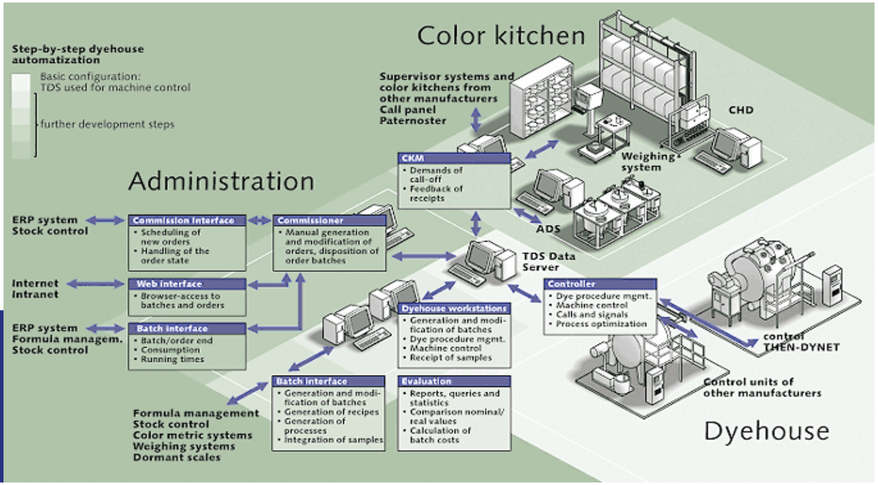
control THEN-DYNET

Control units of other manufacturers

Dyehouse

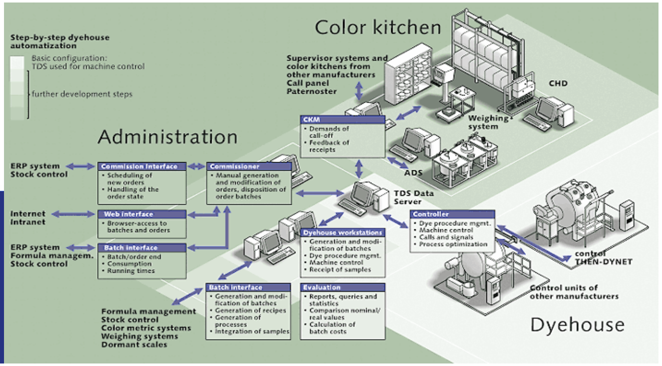
The Then fully integrated dyehouse

- The THEN control product line is an interconnected automation system for dyehouses.
- The automated dyeing machines are linked with the automatic transport and weighing of dyestuffs and chemicals and the management and organisation system of the dyehouse (TDS).
- The TDS integrates THEN products, products of other manufacturers and PC-control systems or host-computers which includes; for example, order handling, recipe formulation systems (Datacolor) and dyehouse support systems for the optimisation of dyehouse processes.

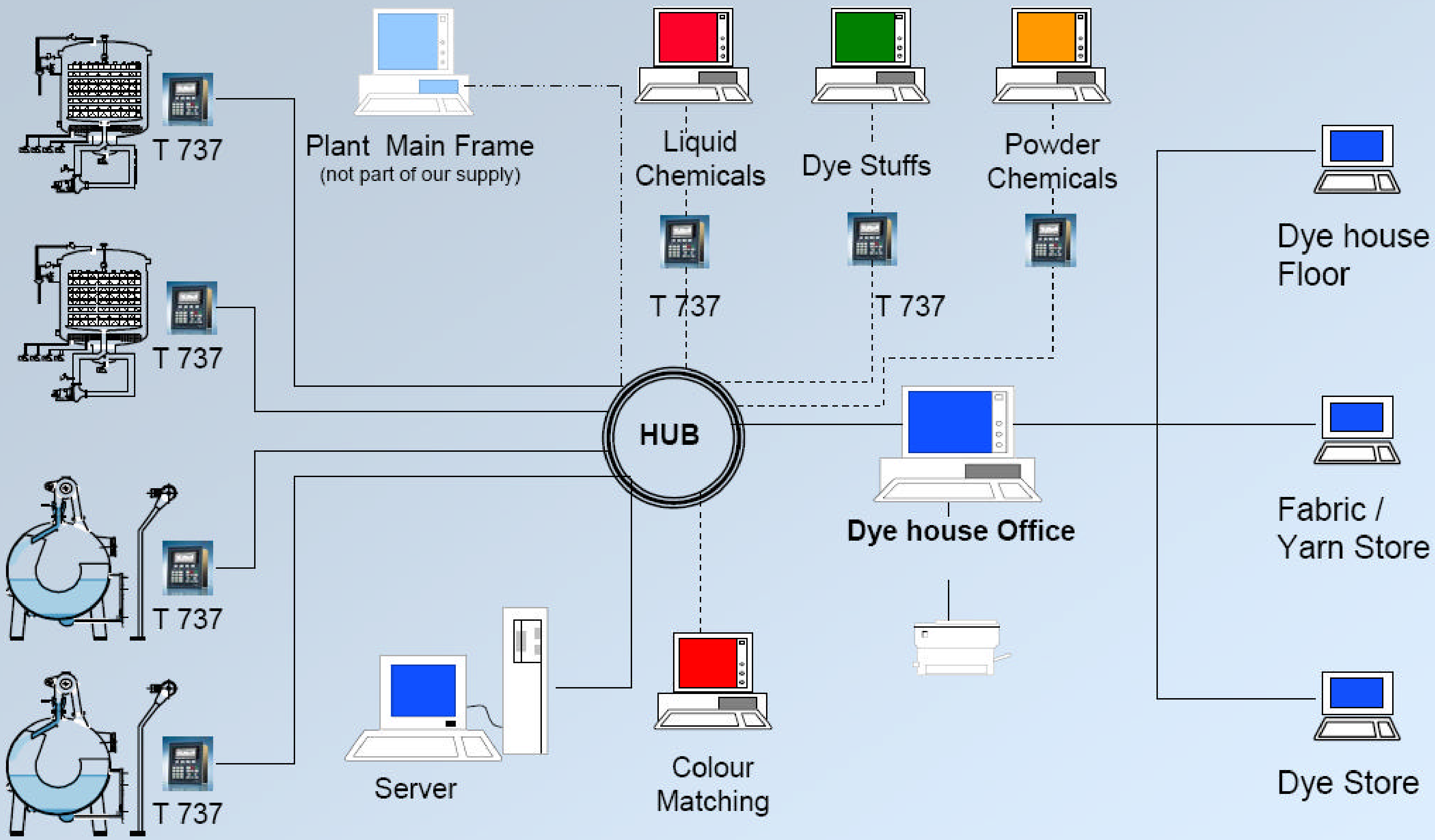


The Then fully integrated dyehouse

- The recipe formulation system provides the production recipes as well as the process-specific data.
- Under a common operating system based on Windows2000/Windows XP, TDS transmits the process programs according to the production schedule to the dyeing machine control units. Production recipes are transmitted to the weighing station, the solving station ADS or the chemical dispensing unit CHD.
- Request requirements as well as ready signals are automatically exchanged between the dyeing machines and the colour kitchen components. From the dyeing machine control units all set and actual values as well as processing alerts are signalled back to the control station.

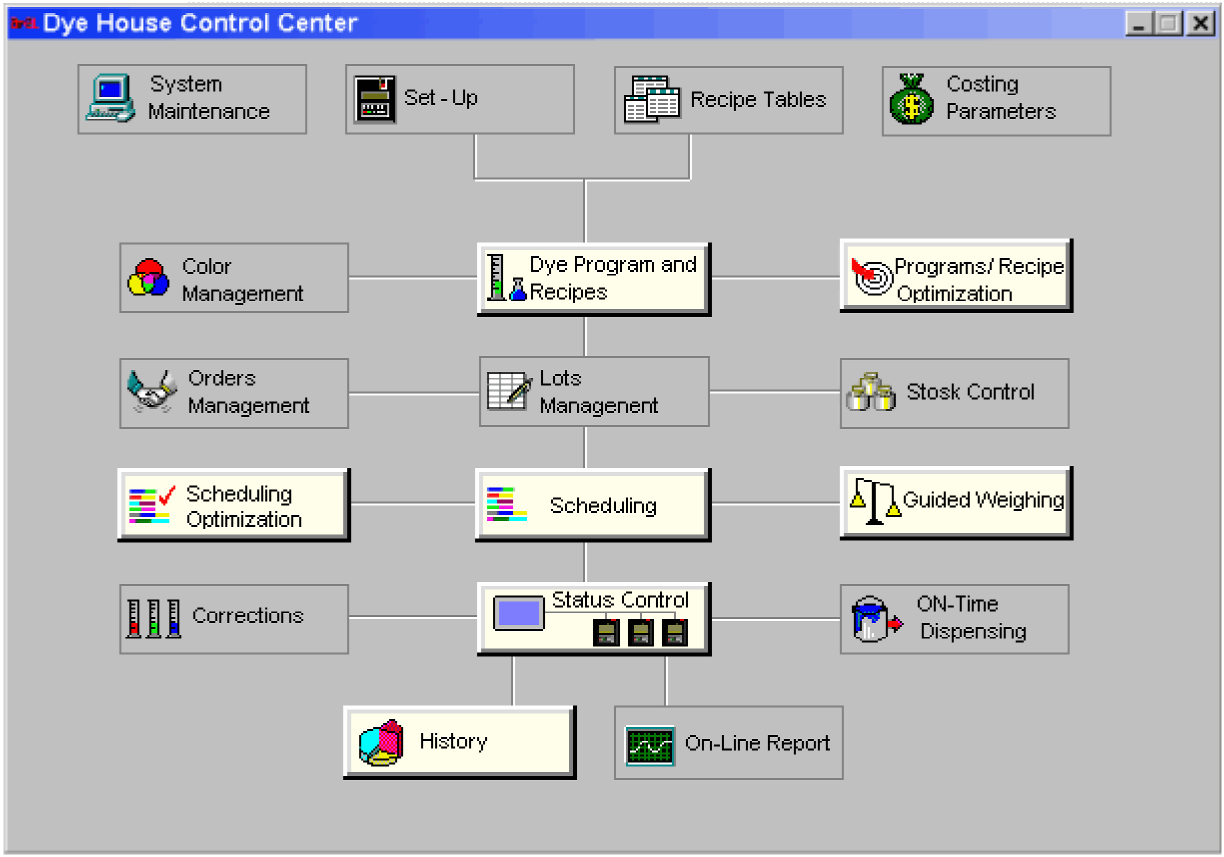


OrgaTEX Dye house - Central Computer System



TEXTILMASCHINEN Thies

Arel dyehouse control centre



Standard Software Modules

"Control Room" basic module, including dye programs management and reporting.

Dye lots creation and maintenance

On-line production scheduling

Look ahead, showing expected MANUAL interventions.

Recipe management

All costing analysis (energy, dyes and chemicals, operation).

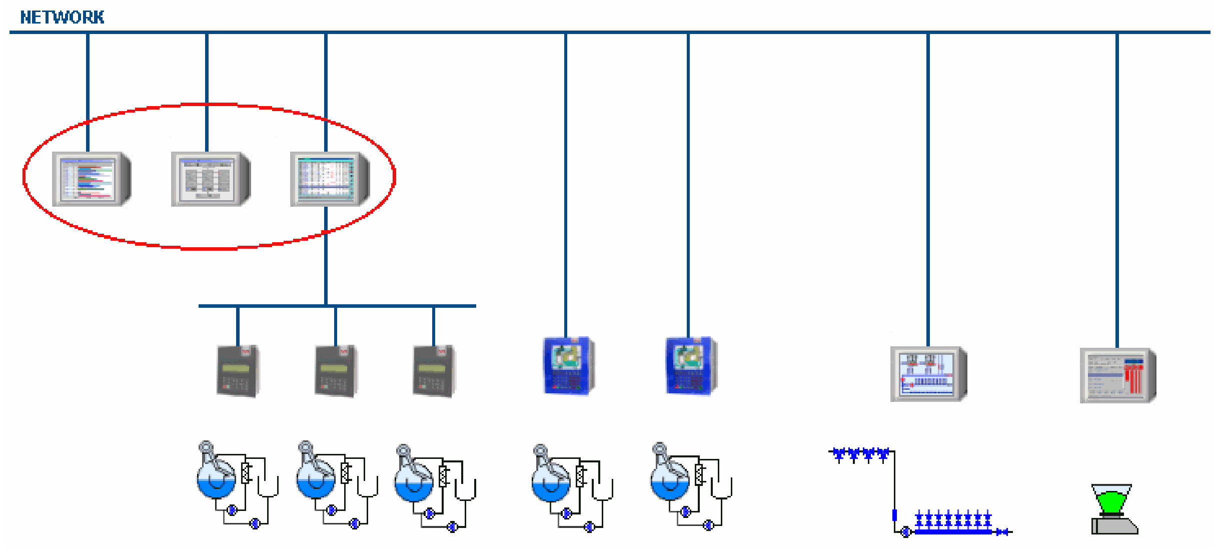
Guided weighing stations

Integration with liquids and powders dispensers

Smart® dye program/recipe optimisation

Smart® Scheduling Optimisation.

Arel dyehouse control system



- The central control hardware is based on a single PC or a PC network. The communication with the machine controllers is carried via a dual ported RAM micro processor-based communication board, or through an Ethernet net work.
- The number of connected controllers is practically unlimited.
- The system runs on Microsoft Windows® platforms, and supports the latest technologies.

Translation of laboratory results to large-scale processing

- A properly integrated system requires that matchings obtained in the laboratory translate into full scale production. This may be very difficult to achieve unless:
  - the dyes and dyeing methods used are sufficiently robust
  - the laboratory and production machines are under automatic control, particularly dye and chemical dispensing and temperature programming
  - operating characteristics of the laboratory and production machines are very similar.
- Machinery manufacturers can assist in providing matching equipment.
- Sometimes conversion factors can be worked out based on experience.

7. Special dyeing methods

Special dyeing methods: cold pad-batch

- Unlike cotton and synthetics such as polyester, there are no commercially viable methods for dyeing wool continuously.
- The reasons for this are:
  - most dyeing batches for wool are too short to justify the set-up costs in machinery and methods
  - wool fabric is too costly to allow for the wastage which inevitably occurs with continuous methods.
- A method for semi-continuous cold pad-batch dyeing of wool was developed by IWS for dyeing wool in the late 1960s.

Cold pad-batch continuous dyeing of wool

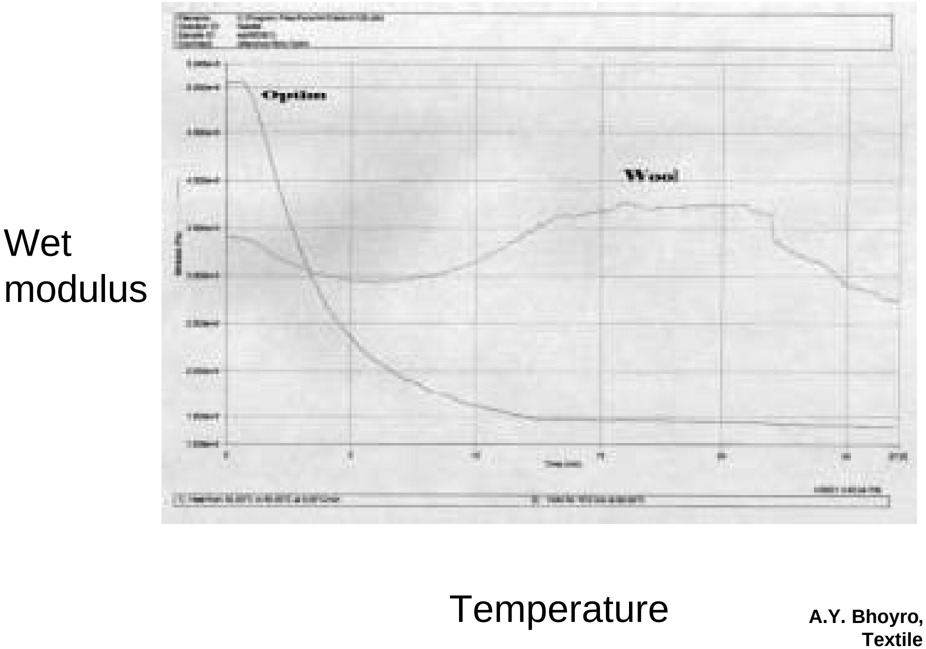
- Wool fabric was padded with dye solution at pH 4.5, and then the goods were rolled up in a batch and stored for 24 hours before washing off.
- This method used Procion MX and conventional wool reactive dyes. The penetration of dye inside the wool fibres at room temperature was accelerated by the presence of 30% of urea in the pad liquor.
- The process failed to gain commercial acceptance because the runs in dyeing wool fabric to plain shades, with a maximum of six pieces per shade, were too short to cover the extra costs of continuous processing relative to piece dyeing.

Special dyeing methods: Optim fine

- Optim fine fibre is whiter than conventional wool and brighter colours, can be obtained, particularly in pastel shades.
- In order to match a given shade, Optim fine fibre requires a higher concentration of dye than normal wool. This is because:
  - the fibres are thinner than normal wool fibres
  - and have different light absorption and scattering properties.
- The rate of dye uptake is greater than normal wool because of:
  - the effect of the reducing reagent used in the stretching process
  - and because the gaps between the cuticle cells are opened up, and dyes diffuse more rapidly into the fibre cortex.

Dyeing Optim fine fibre

- When dyeing tops or packages of Optim fine fibre, unlevel dyeings will be obtained if conventional procedures are followed.
- This is because of a large decrease in the wet fibre modulus with temperature. This behaviour is different from that of untreated wool which shows little change in wet modulus with increasing temperature.
- The progressive decrease in fibre stiffness with increasing temperature results in severe deformation of tops or yarn packages, which in turn leads to channelling of the dye liquor and unlevel dyeings.



A.Y. Bhoyro, J.S. Church, D.G. King, G. J. O'Loughlin, D.G. Phillips and J.A. Rippon, Textile Institute 81st World Conference, Melbourne, Australia, April 2001

Dyeing Optim fine fibre

Package dyeing:

- packages should be parallel sided and precision cross-wound to a higher than normal density
- packages should be compressed wet to a sufficient degree to prevent flow-by when the temperature is raised
- pressure drop across the packages should be low and minimum flow rates employed
- flow should be in-to-out with no reversal
- package weight should be reduced.

Dyeing Optim fine fibre

Top dyeing:

- individual tops can be completely enclosed in a tight elasticised bag
- tops should be compressed on the dyeing spindles after wetting out
- compression should be sufficient to prevent flow-by when the temperature is raised
- pressure drop across the tops should be low and minimum flow rates employed
- flow should be in-to-out with no reversal
- packages should be about half the weight of normal.

Dyeing Optim fine fibre

- Piece dyeing:
  - very gentle action machines (e.g. low draught, overflow types) should be used
  - stretching of the fabric must be avoided at all costs
  - fabric is prone to creasing
  - open-with drying (mangling and stentering) should be used.

Special dyeing methods: Ombré

- Hanks can be produced with a space dyed appearance or garments have a gradual change in colour.
- This type of effect can be obtained by dyeing hanks and garments in open top-loading hank dyeing machines.
- During dyeing, the goods are slowly withdrawn or lowered into the dyebath to obtain a graduated dyeing effect.