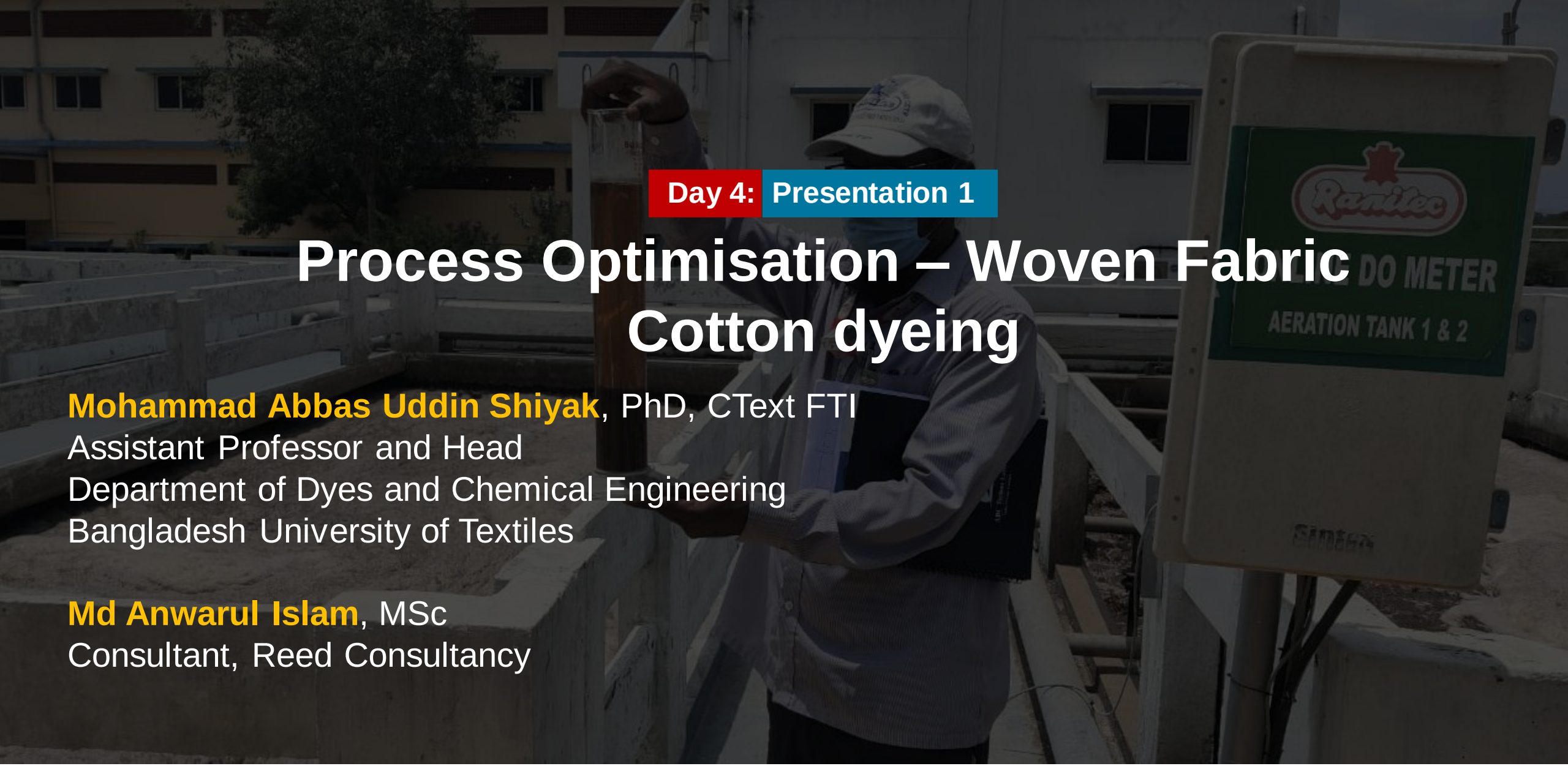
Master Training Program on Water (Water Supply, In-house Processing, End-of-Pipe) in Textile and Garment factories

Promotion of Sustainability in the Textile and Garment Industry in Asia - FABRIC

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

FABRIC Asia



Day 4: Presentation 1

Process Optimisation – Woven Fabric Cotton dyeing

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Outlines

Contents

- **Woven dyeing – Padding dyeing**
  - ✓ Continuous/Semi continuous
  - ✓ Cold pad batch
  - ✓ Finishing
- **Process parameters**
- **Advance Dye Chemistry**

Learning Outcomes

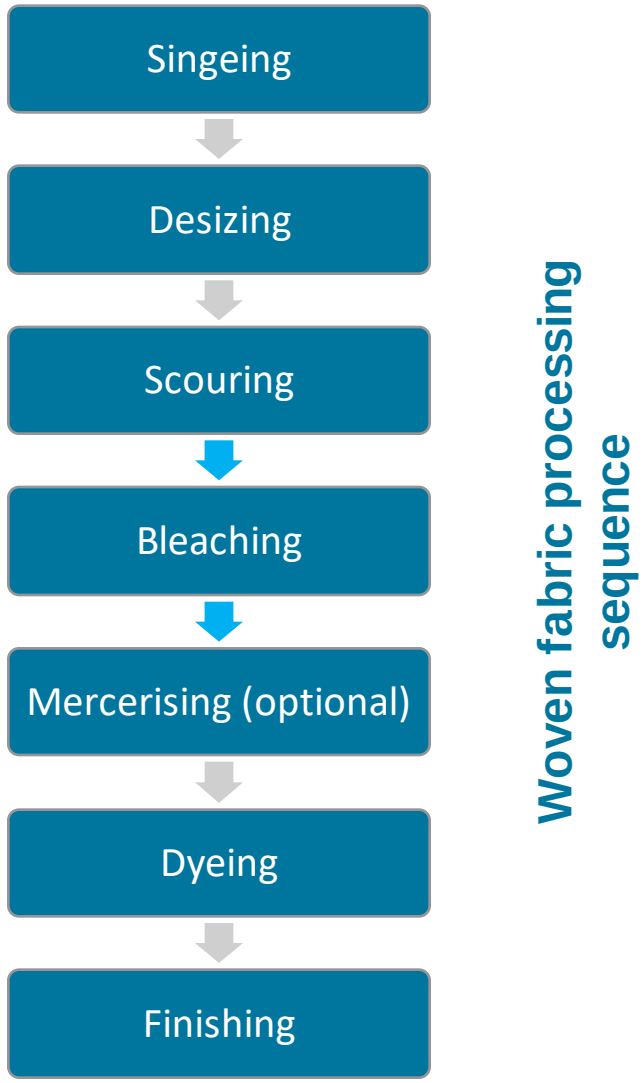
At the end of this module, you will be able to

- Understand the use of water for cotton woven fabric batch dyeing
- assess possible changes and impacts in process steps and production technologies
- apply process specific low water consumption technologies

Water use in continuous/semi-continuous/batch dyeing process for cotton woven fabric

Woven fabric processing sequence

- Singeing/Desizing
- Scouring
- Bleaching
- Mercerising (Optional)
- Heatsetting (for synthetic or it's blend)
- Dyeing
- Finishing



Different types of woven dyeing

Batch Dyeing

- Cold pad batch
- Jigger

Semi-continuous dyeing

- Pad-steam

Semi-continuous dyeing

- Pad-dry-steam
- Pad-steam-pad thermosol

Different types of woven dyeing

Continuous dyeing vs batch dyeing

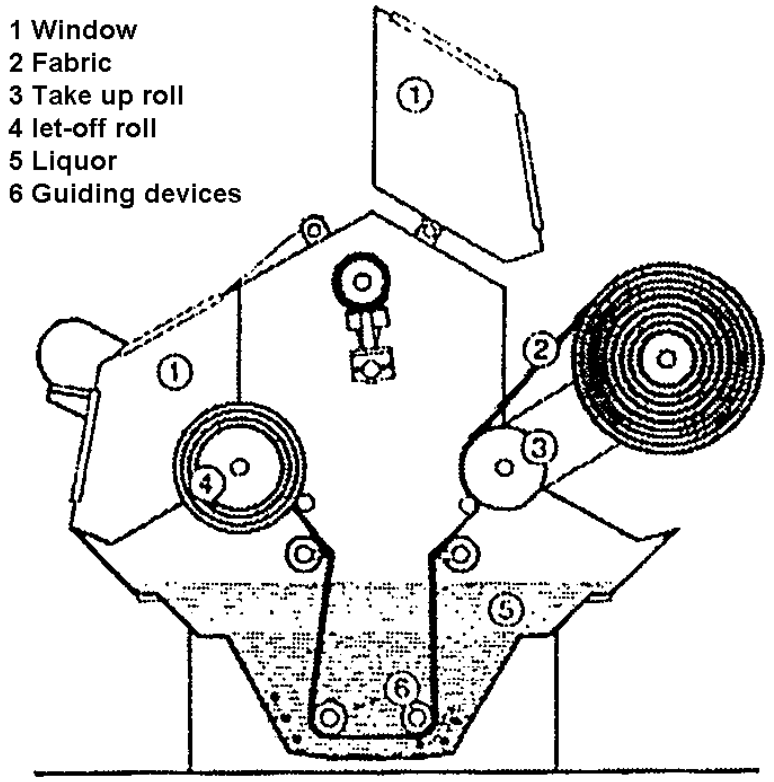
Features	Continuous dyeing	Batch dyeing
Shade uniformity	High degree over width and length and reproducibility	Possibility of batch to batch shade variation
Quality of dyeing	Better	Good
Suitability for garments and uniforms	Suitable	Not suitable
Crease defects	Can be controlled	Difficult to control
Production	High due to short through times	Less due to long dyeing times as it is broken-up in between
Labour requirement	Less	More
Process cost	Less	More

Batch/discontinuous dyeing process for cotton woven fabric

Different types of Batch dyeing

Jigger

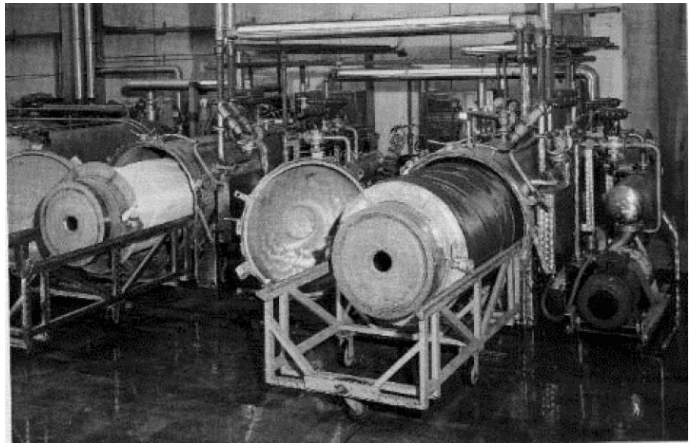
- Oldest types machines used for dyeing woven fabrics up to boiling temperatures
- Can dye most types of fabric construction except very delicate and tension-sensitive substrates
- The dyebath trough has a guide roller or rollers at the bottom through which the fabric passes during dyeing while picking up fresh dye liquor.
- During rotation on the rollers, the dye liquor penetrates and percolates through the fabric facilitating the dyeing action



Different types of Batch dyeing

Beam dyeing machine

- beam dyeing machines were universally used for dyeing polyester and polyester blended fabrics that required higher temperature and pressure
- suitable for dyeing warp knit fabrics, light-weight woven filament fabrics, polyester blended fabrics
- fabric batch remains stationary during dyeing while the dye liquor is circulated through the batch
- During rotation on the rollers, the dye liquor penetrates and percolates through the fabric facilitating the dyeing action



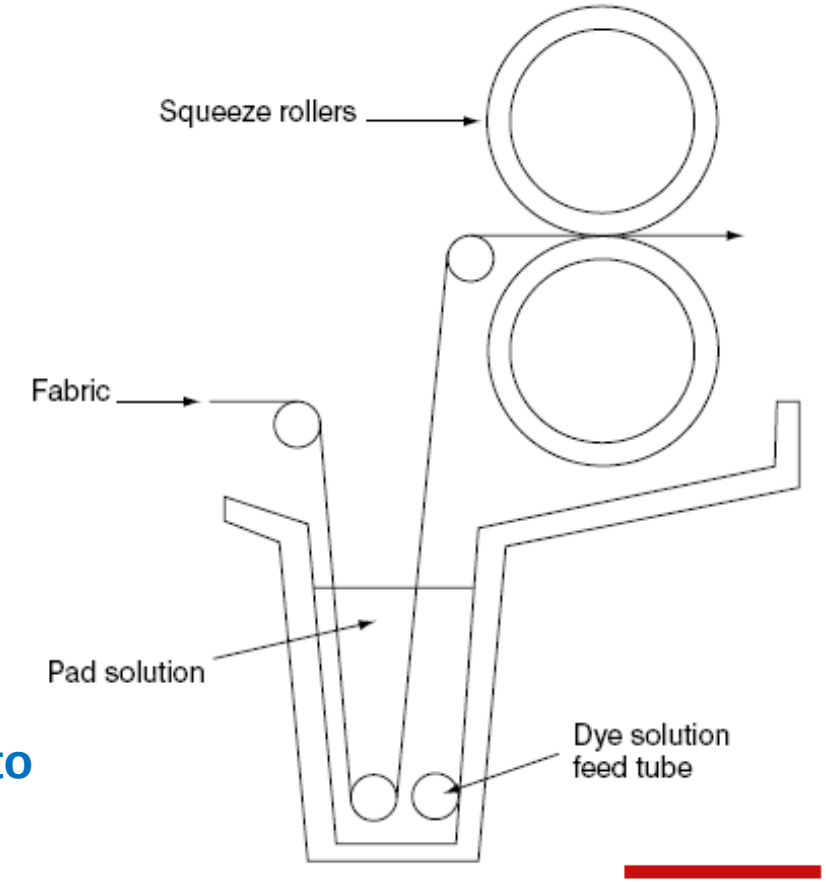
Continuous/Semi-continuous dyeing process for cotton woven fabric

Different types of continuous dyeing

- Cold Pad-Batch
- Pad-Dry-Pad-Steam
- Pad-Steam (all in all)
- Pad-Dry-Thermofix
- Pad-Steam (Wet/Wet)
- Pad-Steam-Pad-Develop
- Pad-Steam-Pad-Thermosol

Padding method of dyeing

- This process is carried out using mechanical means (pad-batch wetting).
- The dyeing liquor is distributed homogeneously onto the fabric (i.e. also the dye is distributed homogeneously).
- In a second stage the dye penetrates into the fabric and is then fixed. At the end of the process the material is washed.
- Pad dyeing is carried out with the fabric in open width form.
- The fabric is passed through a solution of concentrated dye liquor and is then squeezed evenly by a pair of heavy rollers to force the dye into the fiber.



liquor ratio is not of practical importance; the factor to be taken into account is the wet pick-up% and the concentration of the dye.

Wet pick up percentage

- The amount of dye, size, or other fluid by percent weight picked up by the fiber, yarn, or fabric during an application process and calculated per 100 g of dry fabric.

Wet pick up % = g solution/100 gm fibre

- It should be high enough that there is sufficient solution to adequately wet the fibers and yarns and allow the dye to uniformly reach the fiber surfaces, but not so high that there is excessive migration on drying
- The minimum wet pick-up is usually around 55–60% for cotton/polyester materials, 60–70% for cotton, and higher for fabrics of the more absorbent viscose

Calculate Shade percentage from Wet pick up percentage

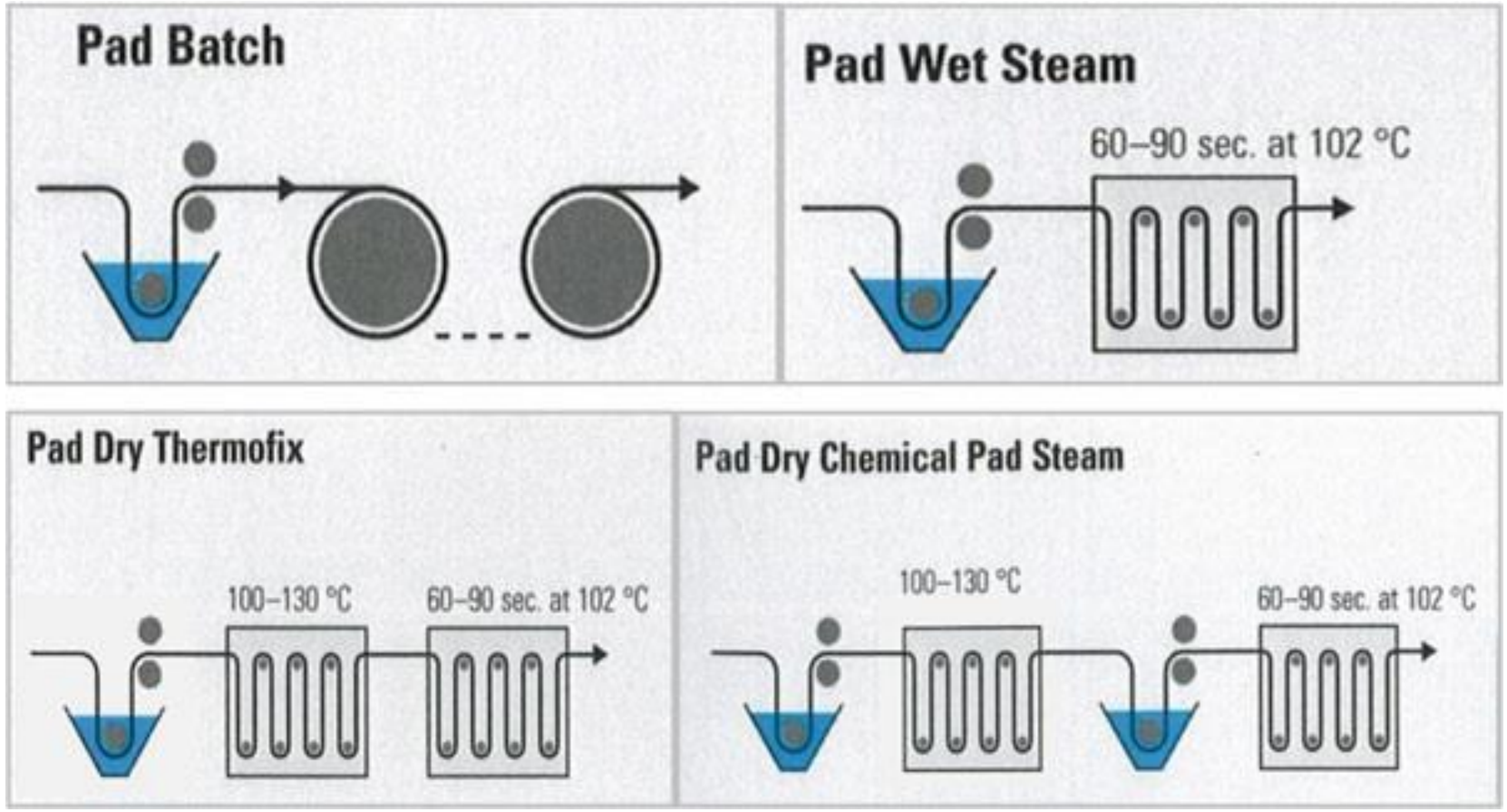
What will be the actual shade percentage when wet pick is 70% and a dye solution containing 1.80% of dye

Wet pick up percentage

$$\text{Amount of dye}\left(\frac{\text{g dye}}{100\,\text{g fibre}}\right) = \text{Wet pick-up}\left(\frac{\text{g soln}}{100\,\text{g fibre}}\right) \times \text{Dye concn}\left(\frac{\text{g dye}}{\text{g soln}}\right)$$

For Example, A 70.0% wet pick-up of a dye solution containing 1.80% of dye is 70 * 1.80/100 = 1.26 % dye (owf)

Different types of continuous dyeing



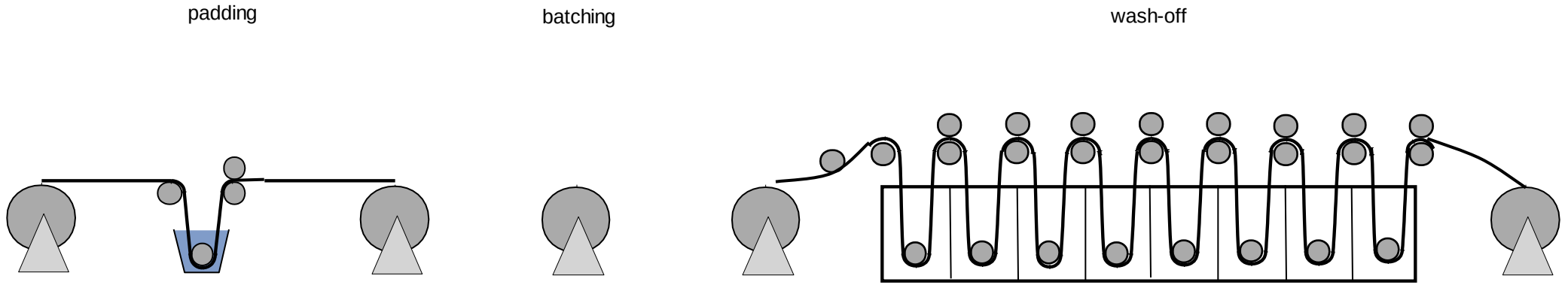
Process profile

Processes	Drying	Fixation (°C)	Fixation medium
Pad-batch	—	20–35	Padding liquor
Pad-wet steam	—	102	Steam 100%
Pad Thermofix	110–130°C	160	Air
Pad-dry chemical pad-steam	110–130°C	102	Steam 100%

liquor ratio is not of practical importance and it is not used as a parameter. In these processes the factor to be taken into account is the wet pick-up % and the concentration of the dye.

Different types of Batch dyeing

Cold Pad Batch process



The processing sequence is as follows:

- Impregnate the well prepared fabric in a cold solution of dye and alkali
- Remove surplus liquor by passing the fabric through a mangle nip
- Batch the padded fabric evenly and wrap in polythene sheeting
- Slowly rotate the roll of wet fabric at ambient temperature for set period
- Wash-off unfixed dye and dry.

Different types of Batch dyeing

Cold Pad Batch process (contd….)

- Optimum temperature of both the pad liquor and the batched roll is around 25°C. If the pad liquor temperature falls below 20°C the colour yield will be reduced, but if it is allowed to rise above 30°C the bath stability will be impaired.
- The cold pad-batch process is a popular and economical dyeing method requiring relatively straightforward dyeing equipment and there is no need for intermediate drying.
- In terms of labor cost, energy and water consumption, it represents the most economical approach to producing high-quality dyeing of high wet fastness on cotton and viscose woven fabrics.
- Pad-batch dyeing is particularly recommended for batch lengths of 1000- 10 000 m per shade.
- Best quality products can be produced particularly suitable for where finish like resin, water repellent applied
- High color yield

Different types of semi-continuous dyeing

- In these mixed systems several operations are carried out with both continuous and discontinuous machines.
- The only difference between continuous and semi-continuous processes is the fact that in semi-continuous dyeing the application of the dye is performed continuously by padding, while fixation and washing are discontinuous.
- These mixed systems are suitable for processing small and medium lots; they require reasonable start-up costs

Continuous dyeing process for cotton woven fabric

Continuous dyeing of woven fabric

- the operations are carried out by means of a series of machines; every machine carries out always and solely the same process. Every machine is assembled according to specific production requirements.
- A system like this entails high start-up costs and a complex setup but once the system has started, it provides highest cost-efficiency
- Excellent repeatability and high output rates

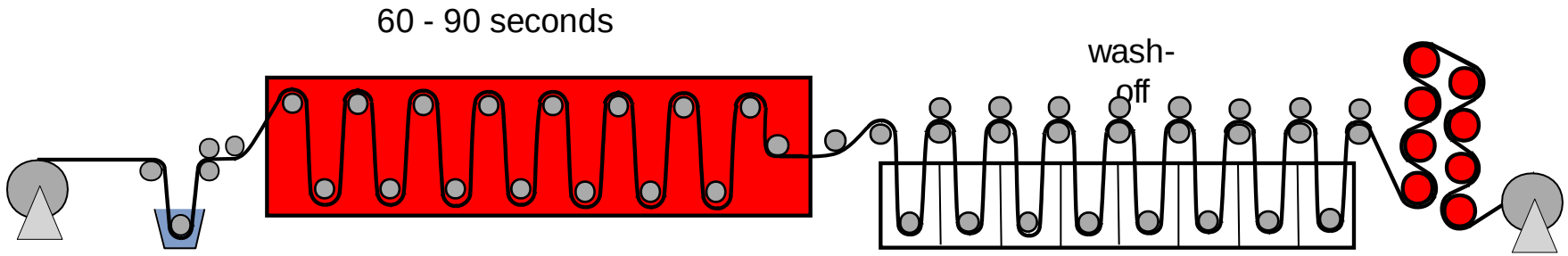
Continuous dyeing of woven fabric

Most continuous dyeing processes can be divided into four stages:

- dye application by padding;
- dye fixation, usually in hot air or steam;
- washing-off of unfixed dye and auxiliary chemicals;
- drying, usually on steam-heated cylinders.

Continuous dyeing of woven fabric

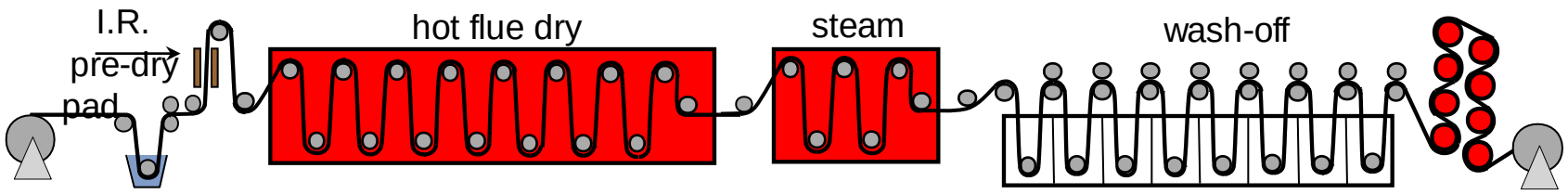
Pad – steam process



- One bath process without intermediate drying
- Mainly suitable for heavy woven fabrics where intermediate drying wouldn't be economical and where there would be a risk of dyestuff migration.
- high productivity
- Particularly suitable for pale to medium shades
- Typically articles are cord, terry towel, regenerated cellulose

Continuous dyeing of woven fabric

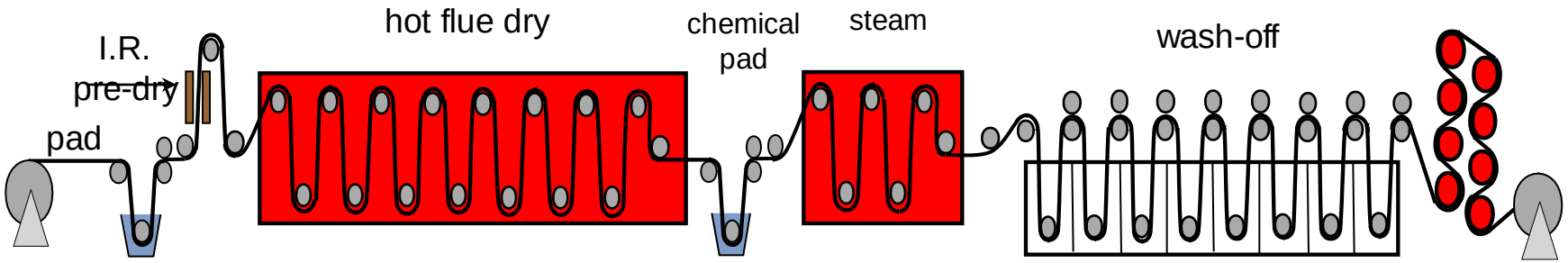
Pad – dry – steam process



- Mainly used for cotton goods and long yardage
- high productivity
- High color yield
- Salt free dyeing
- Far lower migration of dyes
- Good washing off

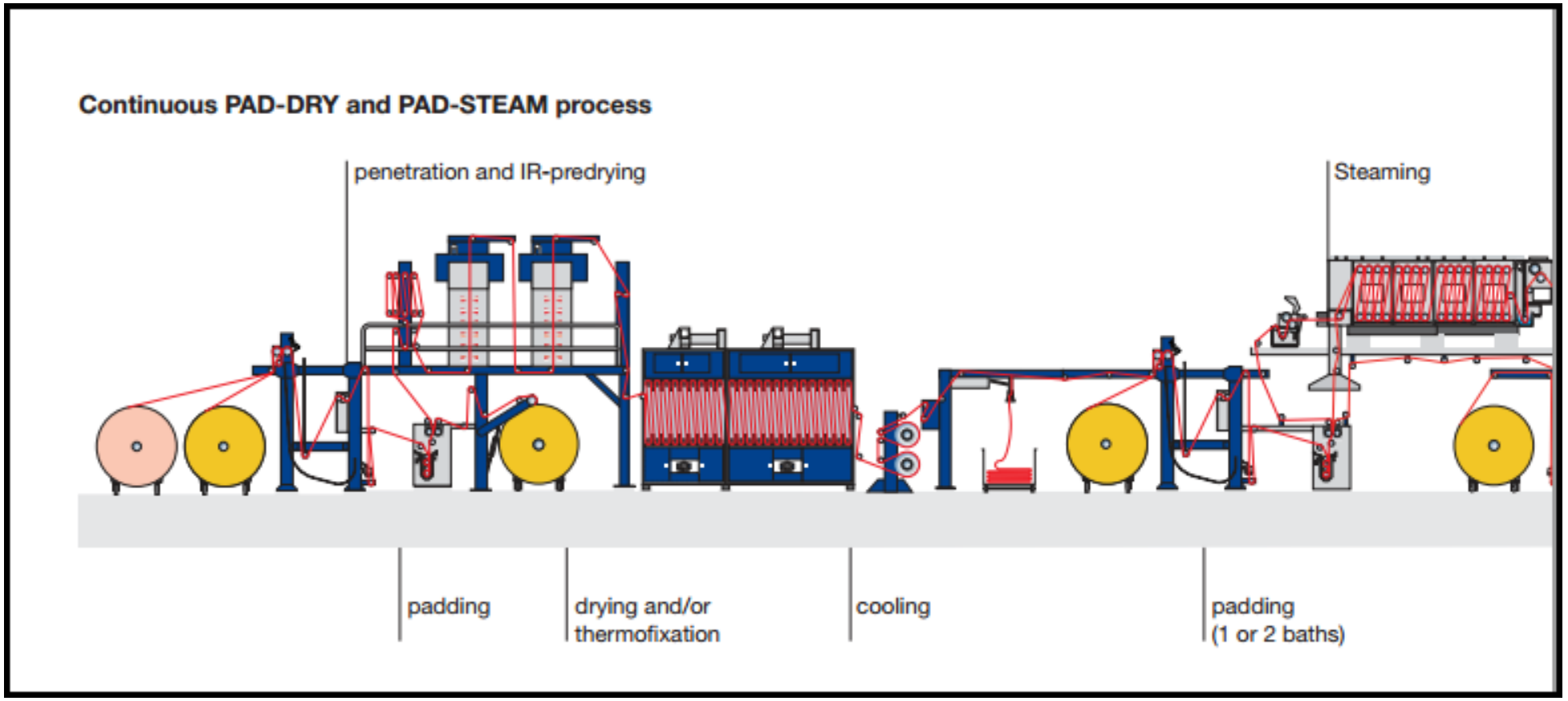
Continuous dyeing of woven fabric

Pad – dry – pad – steam



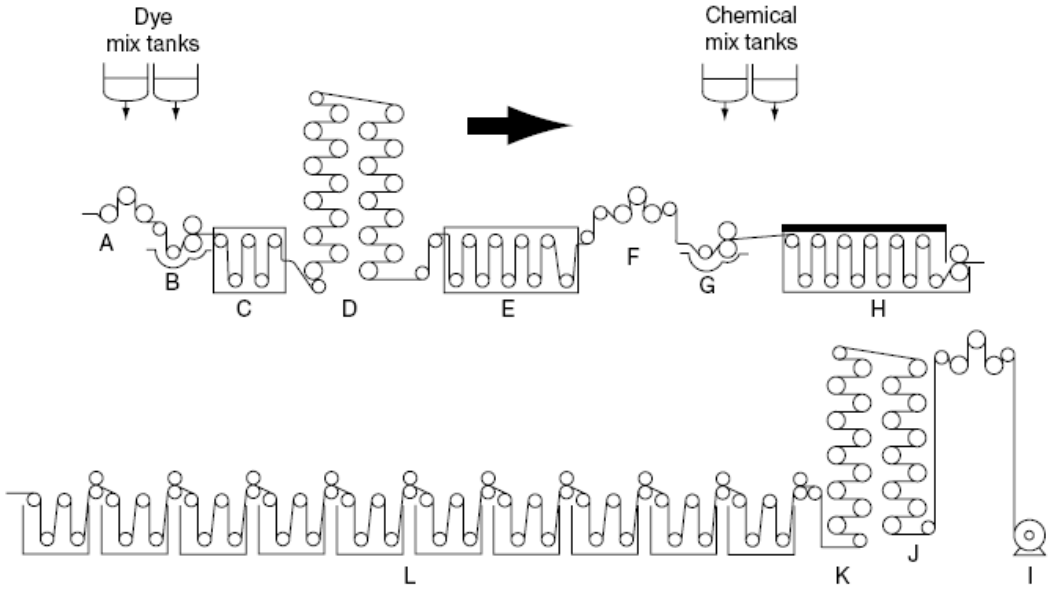
- Primarily for cotton goods and long yardages
- high productivity
- Good appearance
- High color yield

Continuous dyeing of woven fabric



Continuous dyeing of woven fabric

A pad–thermosol–pad–steam for cotton/polyester fabrics



- Reactive dyeing of cotton, salt free one bath method that ensures satisfactorily coverage of dead cotton
- Lower fastness properties
- Usually recommended for dischargeable dyeing, and shades of turquoise and brilliant green, where no other process is suitable

Woven Fabric Finishing

Textile Finishing

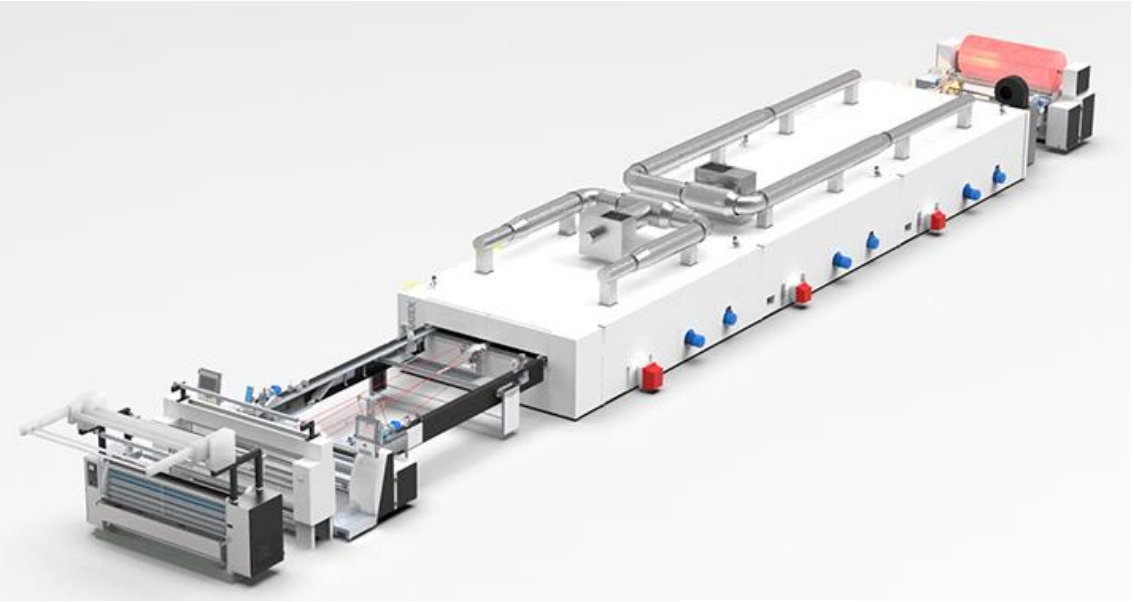
- Descriptive of processes, physical or chemical, applied to a substrate to produce a desired effect.
- Finishing encompasses chemical or mechanical treatments performed on fiber, yam, or fabric to improve appearance, texture, or performance.
- Finishing is commonly divided into two categories, Chemical and Mechanical

Woven Fabric Finishing Machine used

- Stenter
- Sanforising
- Dryer

Stenter

- Most versatile finishing machine
- Involves padding of the liquor on finishing chemical and subsequent fixation and drying
- Also, a machine to control length and width of the fabric
- Shrinkage, spirality and moisture are controlled by this machine

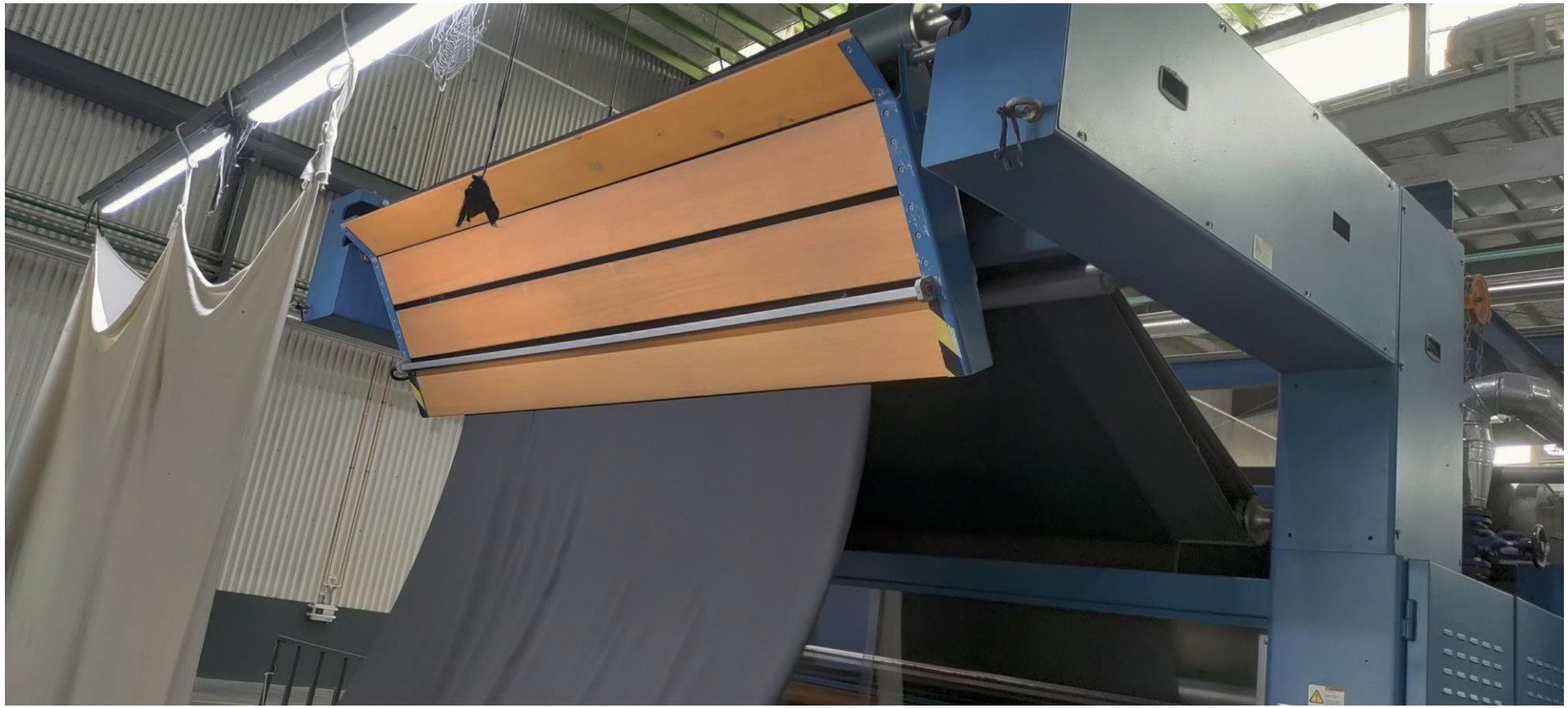


Source: ICOMATEX

Stenter

Stenter

Stenter



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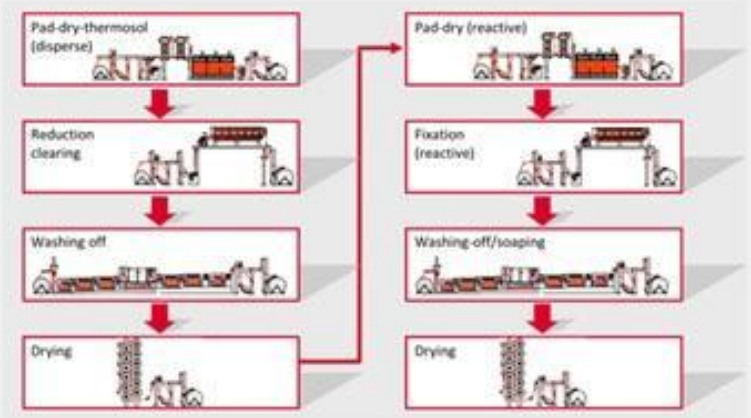
Water Conversation Measures

Pad-dry-thermosol-pad-steam

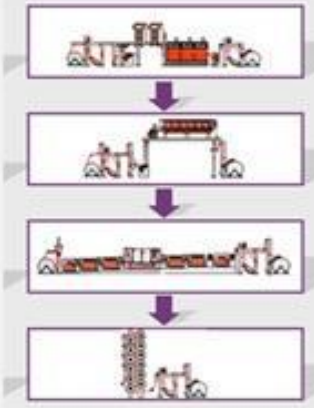
Standard PDTPS process

1. Pad-dry-thermosol (disperse)
2. Reduction clearing
3. Washing-off
4. Drying
5. Pad-dry (reactive)
6. Pad-steam reactive fixation
7. Wash-off
8. Drying



Cadira Reactive/Disperse Continuous PDTPS process

1. Pad-dry-thermosol (disperse and reactive together)
2. Pad-steam reactive fixation
3. Wash-off
4. Drying



Saving:

-41%	Chemicals
-54%	Water
-45%	Energy

Reuse of water from washing and other processes

Reuse of water from washing and other processes

Dyeing after-treatments

Substrate	Dyes group	After-treatments
Cotton or viscose	Reactive	Rinsing – soaping – rinsing or hot counter-flow washing
	Vat	Rinsing – oxidising – soaping – rinsing
	Sulphur	rinsing – neutralizing – oxidising – soaping – rinsing
Cotton/polyester blends	Reactive/disperse	Rinsing – soaping – rinsing
	Vat/disperse	Rinsing – oxidising – soaping – rinsing
Polyester	Disperse	Rinsing – reduction-clearing – soaping – rinsing

Specific water consumption in Washing steps

Achievable specific water consumption levels for continuous washing processes during finishing of open-width woven fabric consisting of cotton or viscose and their blends with synthetic fibres

Pretreatment processes	Water consumption (l/kg)	
	TOTAL	of which HOT WATER
Washing for desizing	3-4	3-4
Washing after scouring	4-5	4-5
Washing after bleaching	4-5	4-5
Washing after cold bleaching	4-6	4-6
Washing after mercerisation - Washing to remove NaOH - Neutralisation without drying - Neutralisation and drying	 4-5 (hot) 1-2 (cold) 1-2 (warm)	 4-5 NA < 1
Washing after dyeing		
Reactive dyestuffs	10-15	4-8
Vat dyestuffs	8-12	3-7
Sulphur dyestuffs	18-20	8-10
Naphthol dyestuffs	12-16	4-8
Washing after printing		
Reactive dyestuffs	15-20	12-16
Vat dyestuffs	12-16	4-8
Naphthol dyestuffs	14-18	6-10
Disperse dyestuffs	12-16	4-8
NB: NA: Not applicable. *Source*: [5, UBA 2001]		

Reuse of Cooling Water from Singeing Machine

- Cooling water is continuously supplied at the inside of the rollers of the singeing machine to keep them cool which become hot by the direct exposure of the flame
- It is a warm water which is wasted and generally not reused
- Its quantity is in the range of 24 to 48 m^3/d which can be reused as:
  - ✓ Washing water in the process
  - ✓ Showering water at wet scrubbers installed with steam boiler
  - ✓ Showering water at wet scrubber installed with singeing machines

Economics
Capital cost = Rs. 150,000 – 300,000
Annual saving = Rs. 0.63 - 1.26 million
Annual O&M cost = Rs. 250,000 - 500,000
Simple payback period = 5.0 months

Reuse of Water from Cooling Drums

- Fabric is cooled at cooling drums after drying at the drum dryers
- Cooling drums are provided with fresh water circulation inside. After getting heat of the hot fabric, this warm water is discharged as wastewater
- This clean warm water can be collected in a storage tank and reused in the process. In some industries, this cooling water is not a raw water but a treated water (soft water or RO treated water) which is of a very good quality and very expensive
- Its quantity is up to 482 m^3/d

Economics
Capital cost = Rs. 3.5 million
Annual saving = Rs. 8.4 million
Annual O&M cost = Rs. 500,000
Simple payback period = 5 months

Reuse of Post Scouring Washing Water as Desizing Washing Water in the Continuous Pretreatment Machine

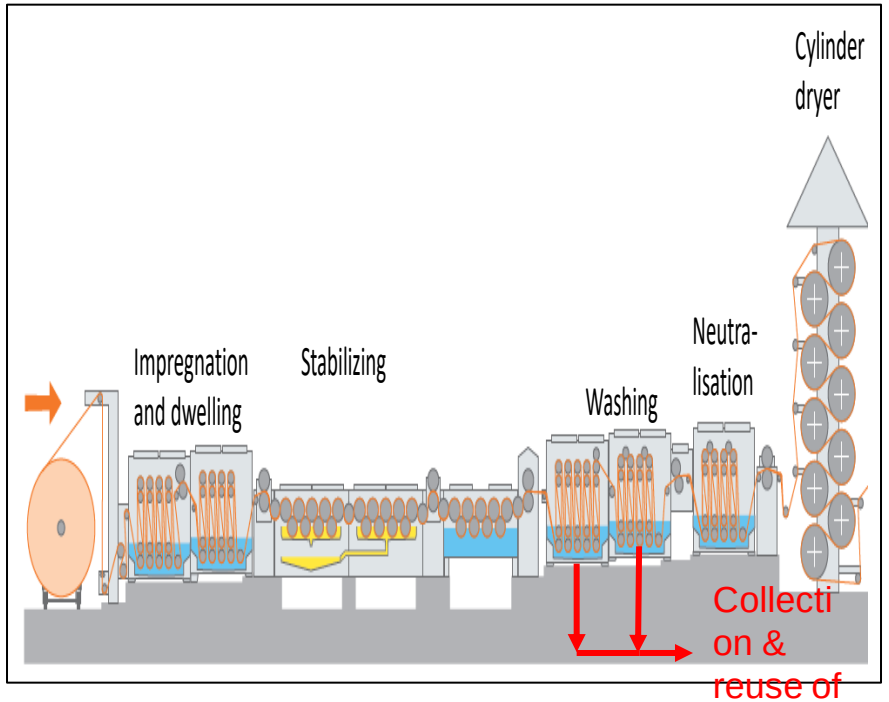
- In the continuous pretreatment machine, the scouring wash water can be reused as desizing washing water by directing discharge pipeline of scouring section wash water into the supply line of desizing wash boxes
- For desizing washing, high quality water is generally not required and scouring wash water can be a good option for such type of washing
- The water in the range of 100 – 170 m^3/d can be reduced at the machine

Economics
Capital cost = Rs. 400,000
Annual saving = Rs. 8.25 million
Annual O&M cost = Rs. 550,000
Simple payback period = < 1 month

Reuse of Post Mercerization Washes

- After the first and/or second wash box, further hot washes, at a temperature of 80oC to 90oC are applied in three to four wash boxes to remove traces of caustic soda from the fabric
- The discharged washing water from these wash boxes is alkaline and contains very low concentration of caustic soda
- This water can be collected in the storage tank and reused as washing water for desizing wash, post scouring wash or post bleaching wash, generally in the continuous pretreatment machine
- Post mercerization washing water is in the range of 50 to 150 m3/d for one mercerization machine

Economics
Capital cost = Rs. 300,000 - 500,000
Annual saving = Rs. 2.13 to 6.40 million
Annual O&M cost = Rs. 400,000 - 600,000
Simple payback period = 1 - 2 months



Reuse of Cooling Water from Different Sources

- There are many sources in the textile industry where cooling water is used and wasted into the drain. These sources are as under:
- Coal based boiler induced fan
- Coal feeding gate of steam boilers/therm oil heaters
- Thermosole padder's hydraulic pump
- Therm oil pumps at therm oil heaters
- Ager therm oil pump
- Calender cooling water
- Comfort cooling water
- Gas based therm oil pump cooling water
- Padders of continuous dyeing machines
- This water is in the range of 100 – 160 m3/ (collected and reused)

Economics
Capital cost = Rs. 0.6 to 1.2 million
Annual saving = Rs. 1.94 to 3.15 million
Annual O&M cost = Rs. 300,000 to 500,000
Simple payback period = 4 to 5 months

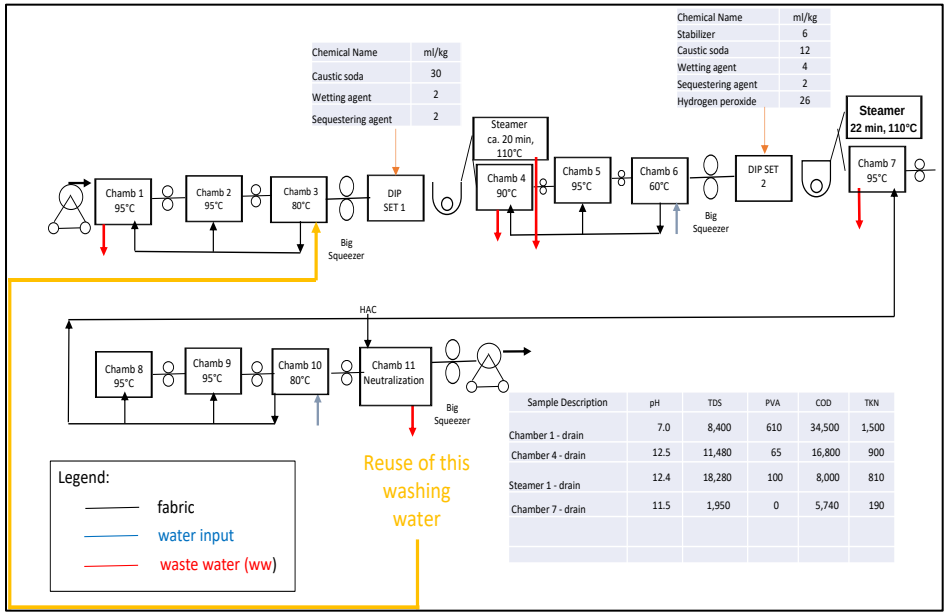
Reuse of Water Lock Water from Steamer

- There is continuous supply and wastage of fresh water at fabric exit point of the steamer. This water is supplied to maintain a water lock so that the steam vapors could not escape from the steamer along with fabric into the atmosphere (loss of steam and increase of humidity of the environment)
- This is relatively a clean water stream which can be collected and reused at the wash boxes of the same machine
- The quantity of this water is 90 – 115 m3/d

Economics
Capital cost = Nominal
Annual saving = Rs. 0.58 - 0.74 million
Annual O&M cost = Nil
Simple payback period = Few days

Reuse of Post Neutralization Washes as Pre Washes at Pretreatment Machine

- After post bleaching washes, fabric is treated with acid for neutralization of the fabric and then washed in the post neutralization wash boxes at about 60oC temperature
- The post neutralization wash water can be reused as pre wash water by directing discharge pipeline of neutralization section wash water into the supply line of pre wash boxes
- This water is in the range of 50 to 82 m3/d



Economics

Capital cost = 200,000 to 400,000
Annual saving = Rs. 1.38 to 2.27 million
Annual O&M cost = 100,000 to 200,000
Simple payback period = 2 to 3 months

Counter-current Washing in Wash Boxes (Compartments)

- In the counter-current washing mode, water and energy consumption is reduced substantially
- The locally manufactured machines are often not designed on counter-current washing mode where each wash box is operated independently with supply of water in the wash box which is heated through steam and then wasted as overflow water
- Counter-current washing is based upon the principle that the dirty fabric is in contact with dirty water and clean fabric is in contact with clean water because the fabric and water move counter-currently
- Example of one industry where water conservation is 590 m3/d

Economics
Capital cost = Rs. 2 million
Annual saving = Rs. 28.69 million
Annual O&M cost = Nil
Simple payback period = 1 month

Heat Recovery from Hot Wastewater

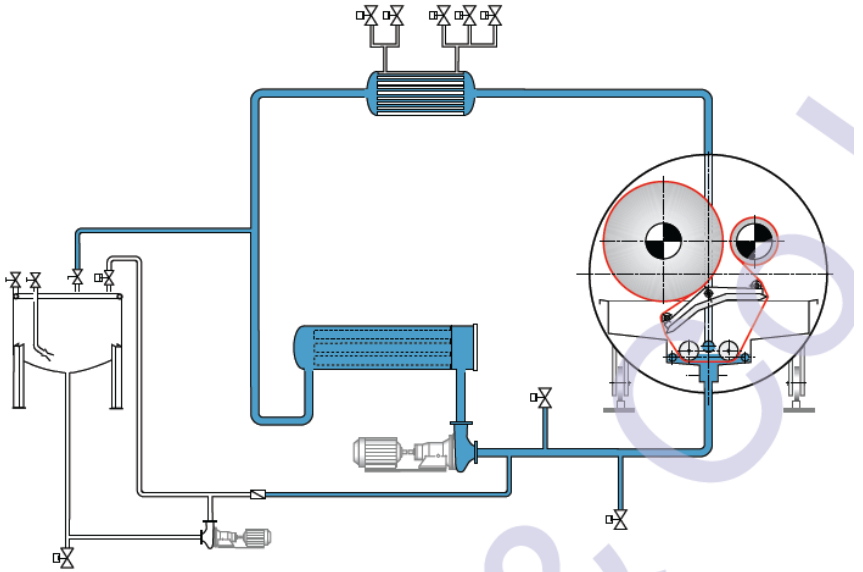
- Extensive hot washes are carried out in the textile finishing industries to wash impurities, undesired chemicals and unfixed dyes and pigments
- Hot wastewater from below mentioned washes (60-95^{o}C) contains substantial amount of thermal energy which costs millions of rupees per year
  - ✓ Desizing/scouring/bleaching washing water
  - ✓ Mercerization hot washing water
  - ✓ Dyeing hot washing water discharge
  - ✓ Continuous post dyeing hot washing
  - ✓ Hot washing water discharge from exhaust dyeing
  - ✓ Washing water from soapers
- Thermal energy from the wastewater streams can be recovered by installing heat exchangers.

Economics
Capital cost = Rs. 1.5 million
Annual saving = Rs. 9 million
Annual O&M cost = Rs. 600,000
Simple payback period = 2 month

Recent Development

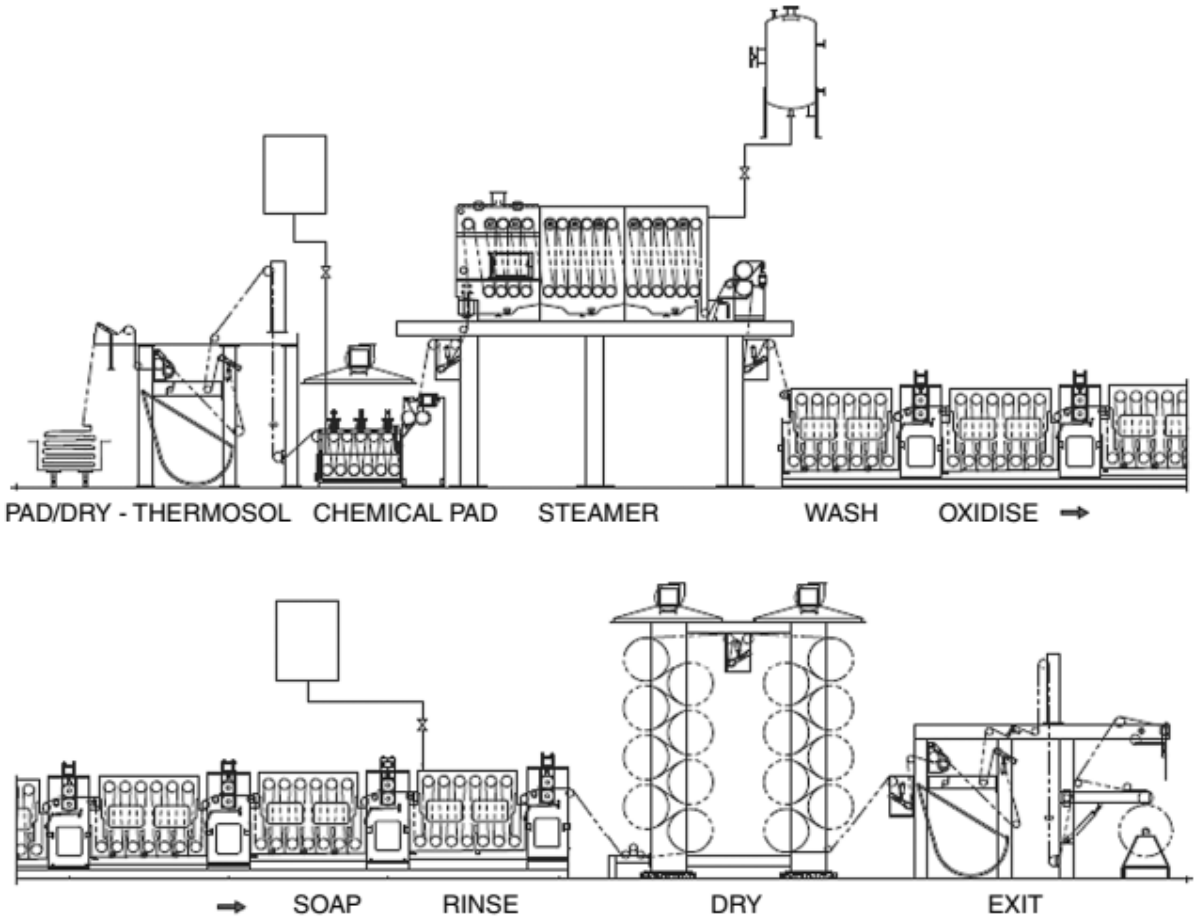
Recent Development

Automatic Jigger dyeing



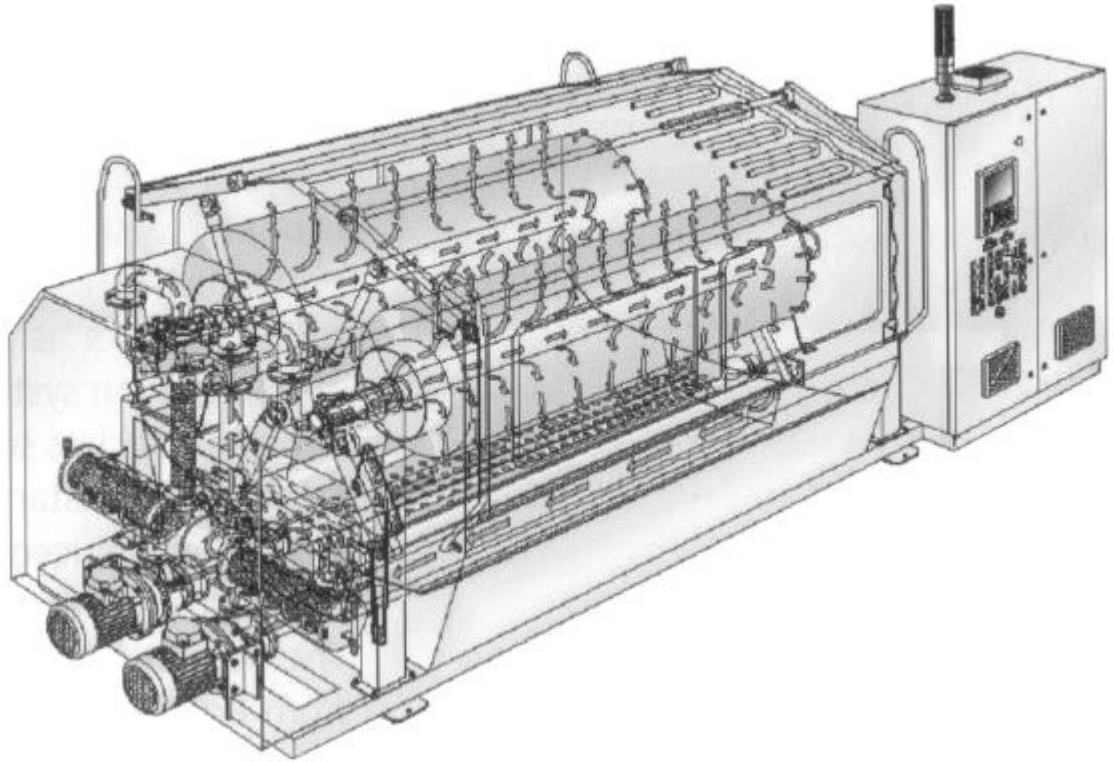
- short liquor ratios
- drastic reduction in water consumption through counter-current flow
- low steam consumption
- low overall processing times.

Universal continuous dyeing range



Reference: Yamuna India

Beam Jigger



Reference:
Brazzoli

- This batch open-width dyeing machine is a combination of autoclave and jigger.
- Designed with a novel liquor flow system, it reduces dyeing time by about 40–50% with a resultant reduction in water and energy requirements

Other water conservation measures

Recovery and reuse of water-soluble sizing chemicals

- Sizing agents are applied to warp yarn in order to protect it during the weaving process and have to be removed during textile pretreatment, thus giving rise to 40-70% of the total COD load of woven fabric finishing mills.

Improved method

✓ After desizing by washing with hot water, water-soluble sizing chemicals (e.g. polyvinyl alcohol and carboxymethyl cellulose) are recovered from the washing water by ultrafiltration.

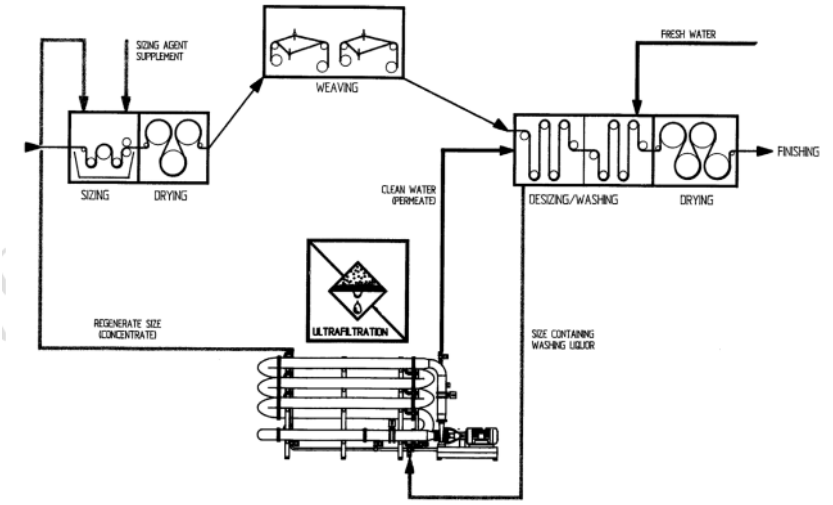
Advantage

✓ Permeate can be reused for washing.

✓ sizing agents can be recovered up to 85%

✓ particularly gentle to fabrics and therefore suited for fine fabric

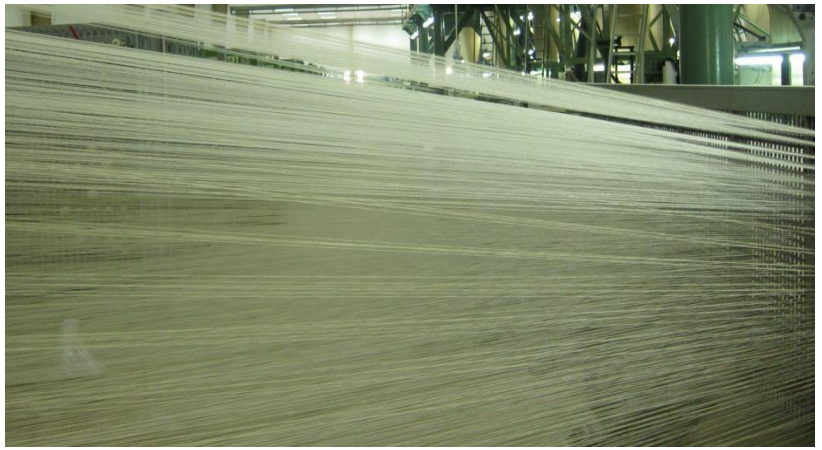
Keep in mind the recovered size needs to be kept under sterile conditions when stored and mixed with fresh size



Source: [5, UBA 2001]

Sizing/Desizing Minimising sizing agent add-on by pre-wetting the warp yarns

- Sizing agents account for 50 to 70 % of the total COD in the waste water of finishing mills
- Minimising the amount of size applied on the warp yarn is one of the most effective pollution prevention techniques for reducing the organic load
- prewetting technology (running the warp yarn through hot water before the sizing process):
  - ✓ allows a more homogeneous sizing effect, increased adhesion of the size and reduced hairiness of the yarn
  - ✓ Reduction of the size add-on of about 20 - 50 %
  - ✓ Improved weaving efficiency in some cases
  - ✓ not applicable to small batches (<5000 m) as the add-on cannot be controlled adequately



Data of a weaving mill:
• 27 % cost savings
•22 % increase in sizing machine speed

BREF Textile Industry Section 4.2.5

Conclusion

Key points to consider

- Continuous and semi-continuous methods of dyeing are water efficient process compared to batch dyeing
- Combination of processes to increase water conservation
- Counterwashing technique and reuse of water/liquor from various processes are important for reduction of water use
- Switching to advanced textile process chemicals (e.g. dyestuff)

Further Reading

- Reactive Dye Selection and Process Development for Exhaust Dyeing of Cellulose (1995) by Al. I. Bradbury, P. S. Collishaw and S. Moorhouse
- Water Efficiency in Textile Industry (WETI) in Pakistan
- Best Available Techniques (BAT) Reference Document for the Textiles Industry, European IPPC Bureau, https://eippcb.jrc.ec.europa.eu/sites/default/files/2020-01/TXT_bref_D1_1.pdf
- Clean By Design: https://www.nrdc.org/resources/green-textile-redux-clean-designs-10-best-practices-offer-even-greater-pollution-reduction
- Handbook of Textile and Industrial Dyeing, Vol 1, Woodhead Publishing

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