# BEST TECHNOLOGY: COLD PAD BATCH DYEING

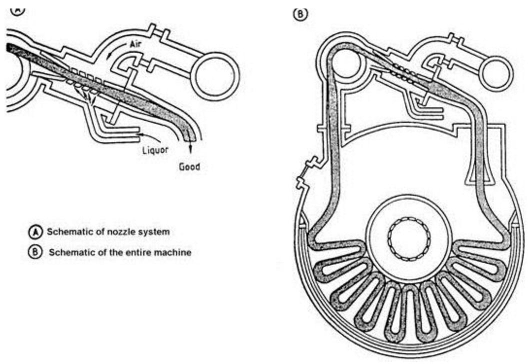
## BACKGROUND AND EXPLANATION

Most cellulosic fashion fabrics – that is those made from cotton, viscose, lyocell, linen and hemp – are dyed using reactive dyes. (other dye types are used, such as vat dyes and direct dyes but reactive dyes dominate the fashion market)

The two most common methods for applying reactive dyes to cellulosic fabrics are:

### *JET DYEING*

Ropes of fabric are transported around a dyeing machine by the combination of winch reels and high pressure jets of dye liquor and dyeing is carried out in warm, highly alkaline dyebaths from very high concentrations of salt.




The salt is used to attract to dyes to the fibre before they become permanently fixed by the addition of alkali. Around 10 -30% of the dye, depending on the specific dye, remains attracted to the fibre but unfixed (on the fibre but not reactively bonded to the fibre) at the end of dyeing and this has to be fully removed so that the fabrics pass colour fastness tests.

Unfortunately the presence of salt makes the removal of unfixed dyed difficult because, in the presence of salt, the dyes prefer to sit on the fibre rather than in the dyebath. The salt has to be diluted with large quantities of water in order to remove the unfixed dye.

Most effluent treatment plants are not designed to remove salt from effluent so large amounts of salt is discharged into water courses which can disrupt the natural balance if there is insufficient dilution.

Jet dyeing can be applied to both woven and knitted fabrics and the bleaching, dyeing and wash-off is normally carried out in the same machine using a single, sequential combined processes.

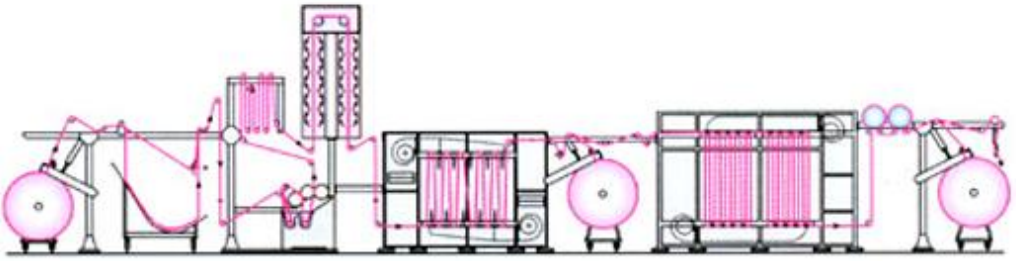
### *CONTINUOUS DYEING*

In continuous dyeing fabrics are bleached, (mercerised), dyed and washed in open width form on 'ranges', which are long, big machines that need to be threaded up with very long pieces of fabric – such as the example below.

It is possible to create modular mega-machines which combine bleaching, mercerising, washing, drying, dyeing, fixing, washing and drying into a single machine several hundred meters long.

Normally dyeing, fixation, wash-off and drying are carried out in a single machine that is around 150 metres long.

The reason for emphasising the size of the machine is because the fabric is ‘festooned’ in the machine – as in the example below – and, even though the best machines can be extremely efficient, it can take up to 500 m to even thread up the dyeing machine.



Continuous dyeing ranges tend to have several sections that use very large amounts of energy per hour – if fabric is being processed the energy per metre is low but lots of energy is wasted when the machine is not actually processing fabric.

Continuous dyeing is therefore only economically feasible for very large batch sizes of thousands of metres and where machine utilisation is high.

In order to avoid permanent creasing the fabrics need to be run under a certain amount of tension and this means that unless very sophisticated controls are employed continuous dyeing is only applicable to rigid woven fabrics.

The dyes are applied using a mangle: fabric is dipped in a trough of dye liquor and fixation chemicals and mangled (this sometimes a two stage process with dyes applied in one trough and chemicals applied separately – the eliminates the risk of alkali rendering the dye non-reactive before application to the fabric). The fabric is usually dried and the dyes are fixed by either the application of steam or dry heat – the diagram below gives a schematic view of the pad trough and mangle arrangement.

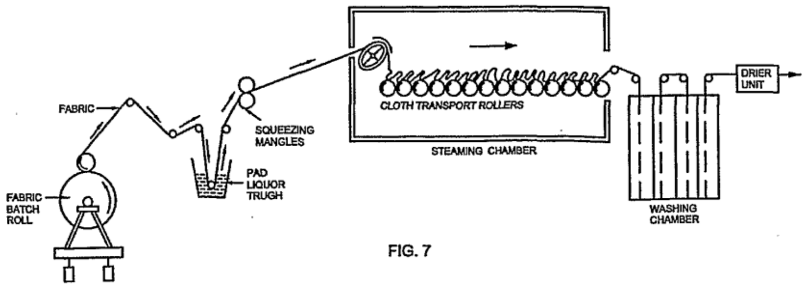


FIG. 7

In order to get good dye fixation in the limited time the fabric has in either a steamer or thermofix unit it is often necessary to add humectants (chemicals that attract moisture), such as urea, to the dye liquor in addition to the alkali used for dye fixation. Urea in effluent is a major problem because it is difficult to remediate (it requires specific denitrification techniques) and if discharged to the environment it acts as unwanted fertiliser and can cause damaging algal blooms.

Salt and/or thickeners are sometimes added to the dye liquors to enhance dye uptake from the pad trough. Salt is an environmental challenge and thickeners (such as alginates) can add considerably to the BOD/COD content of effluent.

***WASH OFF***

The post-bleach and post-dye wash offs can be either a hugely water intensive processes or incredibly efficient depending on the type of machinery used.

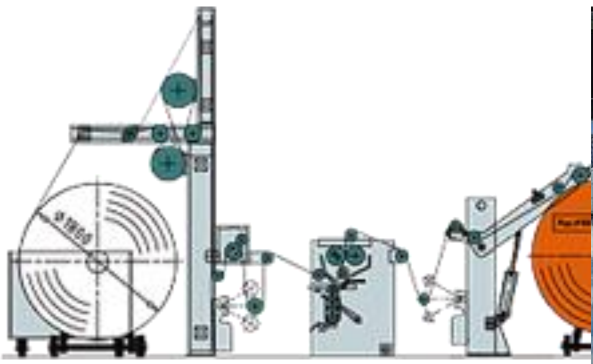
Modern ‘counter-flow’ wash ranges are very impressive in terms of water consumption – the concept is that ‘dirty’ fabric enters the machine at one end and clean water enters the machine at the other. Fabric moves from the front to the back of the machine and gets progressively cleaner and water moves from the back of the machine and gets progressively dirtier.

By the time the fabric exits the machine it is being washed in clean water and by the time the water exits the machine it is quite contaminated but still capable of removing a large proportion of the unfixed dyes and fixation chemicals from the fabric.

Older wash ranges with discrete, sequential wash baths can be very inefficient and use very large amounts of water.

***COLD PAD BATCH DYEING***

Cold pad batch dyeing is closely related to continuous dyeing but it only requires the use of a pad mangle and a means of winding fabric onto a roll – as shown below

The fabric is dipped in a trough containing dye and alkali (typically sodium hydroxide and/or sodium silicate), it is mangled and then wound on a roll without drying it.

The roll is covered in plastic sheets to stop the fabric drying and the batch is slowly rotated for 12 – 24 hours to allow the dye to fix at room temperature.

There is no need to apply heat* and there is no need to use salt or humectants so it is a low water dyeing process, it requires little energy and the absence of salt has the dual benefits of easy dye wash off and no salt in effluent. Additionally there is often a higher % dye fixation compared to jet dyeing.

*The rate of fixation is dependent on the ambient temperature and in countries where there are great differences between summer and winter temperatures it is good practice to carry out dye fixation in a thermo-regulated room.

The contents of the dye pad trough have to be prepared as late as possible before dyeing commences because, even though the alkali is necessary to fix the reactive dye to the fibre, it can also permanently deactivate the reactive part of the reactive dye by a process called hydrolysis – the two reactions (alkali fixing dyes and alkali deactivation dyes) compete in a reactive dyeing process and dyers must minimise hydrolysis to get good levels of dye fixation.

The dye solution and alkali solution are typically pumped to the dye trough independently and mixed immediately prior to dyeing – and there is often the use of a chiller to keep the dye liquors cool to minimise hydrolysis.

Unlike jet dyeing, it is very difficult to make adjustments to off-shade dyeings so it is necessary to get cold pad batch dyeing right first time. However because the dye liquor (minus alkali) is normally prepared well in advance of the dyeing process there is time to conduct laboratory checks and make adjustments.

It is absolutely critical to get a uniform dye application and high quality adjustable rollers are required to get uniform dye application. Side to side variation is a common problem with poor quality mangles.

Fabrics have to be bleached and dried prior to dyeing and it is essential that fabrics have completely uniform moisture content prior to dyeing in order to get uniform dye uptake.

After dyeing the fabrics can be washed off using batch processes (such as a winch or a jet) or, preferably, on a new efficient counter-flow wash range.

Cold pad batch dyeing can save around 50% of energy and water for the whole process compared to jet dyeing provided bleaching and post-dye wash off are carried out on efficient counter-flow wash ranges.

Cold pad batch dyeing can be applied to woven and knitted fabrics (knitted fabrics need careful low tension processing) and, because there is no abrasive processing, the fabrics are much smoother than if processed in a jet dyeing machine – this means smooth fabrics can be obtained without enzyme biopolishing – resulting in stronger fabrics.

**ADVANTAGES OVER JET DYEING**

- Much reduced water consumption (if counter-flow washing ranges used)
- Cold process - Much reduced energy consumption
- Slightly higher dye fixation
- No salt required
    - Easier post-dye wash off
    - No salt in effluent
- Fabrics are smoother
    - No need for biopolish
    - Fabrics are stronger than biopolished equivalent
- Opportunity to do pre-dye checks to improve right first time
- Productivity – one machine can dye far more fabric than a jet machine

**LIMITATIONS AND DISADVANTAGES COMPARED TO JET DYEING**

- Requires investment in specialist equipment
- Best results achieved by continuous bleaching and washing – requiring large investment
- Difficult to make amendments to off-shade batches so pressure to get things right first time
- Process not viable unless high quality kit is used
    - Side to side variation results in fabric rejections
- Requires off-line bleaching and wash off which makes planning more complex
- Requires an intermediate drying process after bleaching
- Requires fabrics to have completely uniform moisture and temperature throughout to achieve optimum results
- Ideally requires a chiller for dyes and thermo-regulated room for dye fixation

**ADVANTAGES OVER CONTINUOUS DYEING**

- No humectants needed, salt should never be used
    - Lower effluent loading
- Cold dye fixation – energy savings
- Can be applied to small batches of a few hundred meters
- Turn round times between colours is very low
- No energy being wasted when the machine is not dyeing fabric
- Better suited to stretch fabrics and knits because it's easier to manage tension control in a small machine

**LIMITATIONS AND DISADVANTAGES COMPARED TO CONTINUOUS DYEING**

- For large batch sizes the logistics of producing multiple 'small' batches using a 3/5 step process bleach-[dry]-dye-wash-[dry] are more complex than a single pass down a continuous range

**WHEN SHOULD COLD PAD BATCH DYEING BE PROMOTED?**

Cold pad batch dyeing should be promoted over jet dyeing in most instances where it is a suitable method for the cellulosic fabric in question.

It may not be suitable for some very lightweight, stretch fabrics that can distort easily and these may be better suited to a horizontal jet dyeing machine (see separate best practice note)

Cold pad batch may only be the appropriate choice from a water and energy perspective where efficient counter-flow wash ranges are used for post-bleach and post-dye wash off.

Where salt in effluent is an issue (unless the receiving waters for treated effluent discharge can adequately dilute salt) cold pad batch dyeing should be the method of choice.

Some jet dye mills can remove salt from effluent using reverse osmosis and vacuum distillation but this is incredibly energy intensive.

It should be ensured that dyers have good quality equipment (and carry out weekly pad mangle checks) and have chillers for dye liquors and thermo regulated rooms for dye fixation where appropriate.

Finally it should be noted that fabrics produced by cold pad batch are smooth and strong but they are susceptible to surfacing on consumer washing and tumbling if poor quality, hairy yarns are used. If low quality yarns are used and require biopolishing it is generally more convenient to conduct all processes on a jet dyeing machine.