CHAPTER 6

MECHANICAL ASPECTS OF CHEMICAL FINISHING

When chemicals are used to change fabric properties, they must be applied uniformly throughout the fabric and fibers. Chemical finishing steps involve applying a chemical solution with a suitable applicator, removing water (drying) and heating the fabric to a temperature that activates the chemical (curing). The process is often referred to as pad-dry-cure. Each part of the process can influence the outcome of the treatment. This chapter will focus on the equipment used in chemical finishing.

I. FINISH APPLICATORS

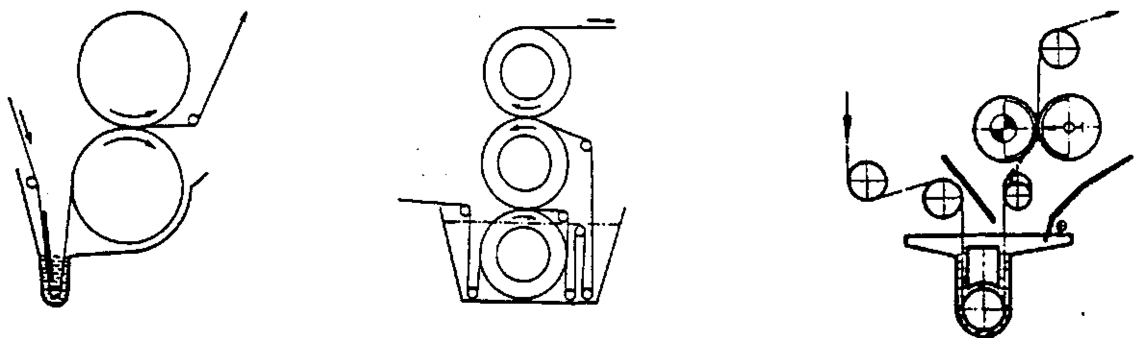
Traditionally, padders have been used to apply chemical finishes. More recently, the cost of energy as it relates to the cost of finishing fabric has escalated interest in low wet pick-up techniques. This section introduces some of the more common apparatus found in a finishing plant.

A. Padder

A padder consists of a trough and a pair of squeeze rolls (mangle). The fabric passes under a submerged roll in the trough filled with the treatment bath and then through squeeze rolls. The process is called padding. Figure 1. shows several types of padders. Diagram (A) is the simplest arrangement, a single dip followed by a single nip. Only two squeeze rolls are used as the mangle. In diagram (B), three rolls are used and the fabric is impregnated twice, double dipped - double nipped. This insures better wet-out and penetration of the finish. Diagram (C) shows a horizontal arrangement of the squeeze rolls.

Three factors control the amount of solution remaining on the fabric, squeeze pressure (which is influenced by the composition of the rolls), fabric construction (the solution resides in the capillary spaces between yarns and fibers), and the absorptive nature of the fiber. All fabrics have upper and lower wet pick-up limits. Within these limits, adjustments in wet pick-up can be made by increasing or decreasing the squeeze pressure. If the squeeze pressure is too low, puddles of solution will remain on the surface of the fabric. When this is dried, excess chemical will deposit in the overly wet areas resulting in non-uniform treatment.

Figure 31. Padders



(A). Single Dip-Single Nip (B) Double Dip-Double Nip (C) Horizontal Configuration

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1. Location of Padded Liquid

When textile fibers are wetted with a liquid, the liquid can either penetrate into the fiber cross section or remain on the surface. The hydrophilic nature of the fiber will determine where this liquid will be. Cellulose and wool fibers will absorb water; therefore, a certain portion of the wet pick-up will be inside the fiber - the rest will be on the fiber's surface. The amount of surface liquid will be influenced by the yarn's interstitial spaces and the spaces between yarns in fabrics. Polyester fibers, being hydrophobic, do not absorb water so the entire wet pick-up will be located in the capillary spaces within the yarns and fabrics. Wet pick-ups in the range of 75 to 100%are common by padding. Usually the baths contain 10%active chemical and the rest is water. The bulk of what is applied must be removed by drying. It takes 980 BTU'S of heat to evaporate one pound of water so the more water that is on the fabric, the more it will cost to dry. It follows then that if the solution has a higher concentration of active ingredients, the same quantity of chemical can be delivered by lowering the wet pick-up. Less energy is needed to dry the fabric because there is less water to evaporate. With less water to evaporate, the range can be run faster increasing the amount of fabric produced in a given unit of time. Production cost are significantly lowered - lower energy cost and higher through put.

There are several techniques that can be used to apply more concentrated solutions at wet pick-ups lower than can be achieved by padding. The major concern with low wet pick-up applicators is uniformity of deposition. These **Low Water Applicators** are:

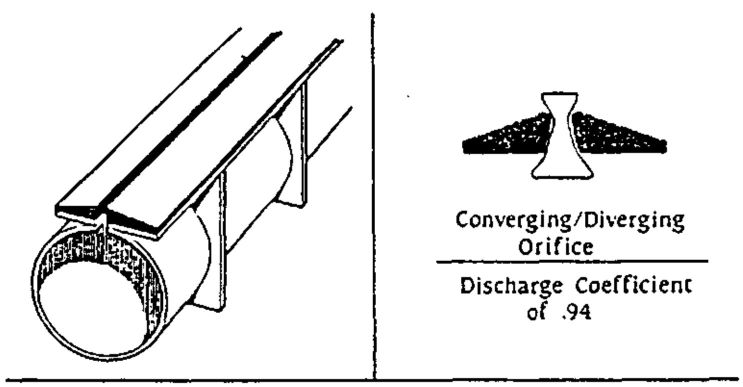
B. Vacuum Slots

Water in capillaries and spaces between fibers and yarns is not bound as strongly as water in the interior of the fiber. The amount in the pores and spaces can be reduced by passing the fabric over a vacuum slot. Figure 2 shows the cross-section of a vacuum slot. It consists of a hollow tube with a slot orifice running the length of the tube. A vacuum pump is connected to the end of the tube and fabric passes over the orifice. The orifice is designed to get the greatest pressure drop through the fabric. An automatic slot seal covers the portion of the slot left uncovered by the fabric and insures maximum vacuum efficiency through the fabric.

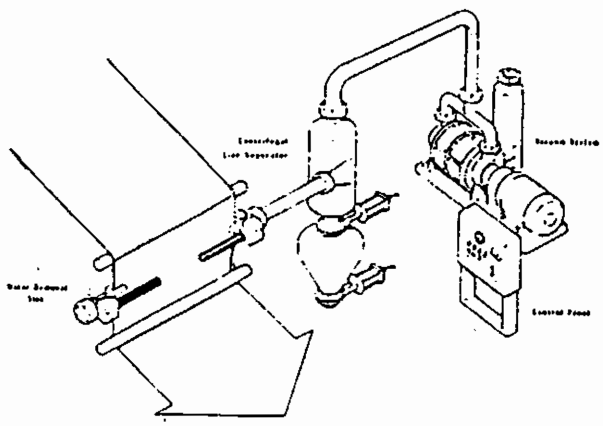
If a vacuum slot is added in line with a padder, the vacuum will extract the liquid residing in the fabric capillaries and open spaces reducing wet pick-up. Most of the solution that remains will be located where it will do the most good, in the interior of the fiber. Finish location and how it influences fabric properties will be discussed in a later section. The finish can be recycled back to the pad for reuse - usually it passes through a filter first to remove lint coming from the fabric.

Figure 32. Vacuum Extractors

Vacuum Tube and Orifice



In Line Slot, Lint Filter and Vacuum System



1. Advantages of Vacuum Slots

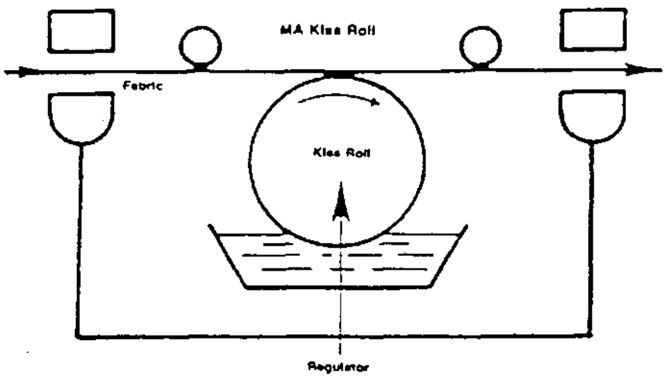
1.They are relative simple devices and are easily fitted onto existing finishing ranges. 2. The extracted solution can be saved and fed back to the pad after the lint has been filtered out. Most fabrics will have short fibers (lint) that come out with the extracted solution. 3. The entire fabric is exposed to the treating solution, therefore the solution is uniform throughout the fabric cross section. Face-to-back uniformity is good. 4. Units have been designed that have movable slot openings to accommodate the need to process fabrics of different widths.

C. Kiss Rolls

A kiss roll applicator consists of a drum rotating in a trough containing the finish. A layer of liquid is picked up by the drum surface. This liquid is transferred onto a fabric "kissing" the exposed section of the drum. Kiss roll applicators are relatively simple devices. Within certain ranges, the wet pick-up can be adjusted to meet whatever is desired by controlling the variables stated above. However, uncontrolled variations in fabric speeds or drum rpm will cause unwanted variations in fabric properties. Figure 3 shows the schematic of the Tritex MA kiss roll applicator. The guts of the unit is a kiss roll rotating in the finish reservoir. Guide rolls position the fabric to contact the wetted surface. This system has beta gauge moisture sensors ahead of and behind the kiss roll to monitor and control wet pick-up. The sensors are connected with speed controllers that adjust either the fabric or the roll speed accordingly.

Figure 33. Kiss Roll Applicator with Moisture Monitors

Triatex MA Kiss Roll



1. Factors Affecting Wet Pick-Up

1. The speed of the fabric travelling over the drum, the faster the fabric travel, the lower the wet pickup, 2. The number of drum revolutions per minute, the greater the number of revolutions per minute, the higher the wet pickup, 3. The viscosity of the liquid controls the thickness of the film on the drum surface. More liquid will be delivered from a viscous liquid than from a less viscous one.

D. Engraved Roll Applicator

Engraved rolls similar to ones used for rotogravure printing can be utilized as low-water finish applicators. In this technique, an etched metal roll revolves in a trough of finish. A "doctor" blade wipes off the surface leaving liquid only in the engraved depressions. The liquid in the engravings wick into the fabric as the fabric passes between the engraved roll and a pressurized backing roll. Engraved roll applicators have advantages over kiss rolls because wet pick-up is not influenced by changing fabric speeds, the depth of the engravings are responsible for metering the liquid. One disadvantage is that the roll must be changed, causing machine down-time, when one wants to change wet pick-up.

Figure 34. Engraved Roll Applicator

E. Foam Applicators

Foam, a collection of bubbles, is created when air is whipped into a liquid. Since a bubble is a sphere of air entrapped by a thin layer of liquid, a volume of foam can be considered a quantity of liquid diluted by air. The volume of foam produced by an amount of liquid is called the ***Blow Ratio.*** Blow ratio is a way of describing foam density since collections of large bubbles result in low density foams whereas small bubbles yield higher density foams. Not all liquids foam when whipped with air. Pure water alone will not foam, a surfactant must be added to lower the surface tension before it will foam.

A volume of foam will eventually break and revert to the original amount of liquid. The time it takes for a foam to revert back to liquid is called ***Persistence*** and the foam's persistence depends on the strength of the bubble's liquid wall. For example, if water drains easily, the bubble's wall become thinner and breaks. However, drainage is influenced by the liquid's viscosity. Water soluble macromolecules, (thickeners) increase viscosity and therefore prolong the time it takes for the cell wall to drain. This will increase the life of the foam and therefore these foams are said to be more persistent.

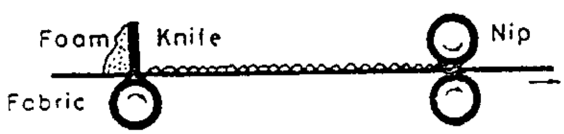
Many textile finish formulations can be foamed by incorporating a foaming agents into the bath. A foaming agent is a surfactant that lowers the surface tension of the bath. The foam's persistence can be controlled by adding water soluble macromolecules. These foams can be metered onto fabrics and represent another low-water application technique. Foamed formulations that break quickly are called ***Metastable Foams*** and those that last are called ***Persistent Foam.*** Each type can be metered onto fabric however, different types of applicators are required. Persistent foams can be applied with knife-coating equipment, while metastable foams require equipment where the foam is generated and applied at the same time.

1. Knife Coaters

A knife-coater is a metering device that continuously spreads viscous liquids onto fabric. This type of equipment is commonly used in the coated fabrics industry. It consists of a stationary knife blade positioned over a fabric support. The material applied to the fabric is fed to one side of the knife blade as the fabric moves continuously under the spreader. The amount deposited on the fabric is controlled by the gap formed between the blade and the fabric. An example of a knife-coater is seen in figure 35. There are several ways the fabric can be supported while moving under the applicator. The fabric can pass between the knife blade and either a table or roll placed directly underneath. These applicators are called knife-over-table and knife-over-roll. Another arrangement has the fabric supported between two horizontal rollers and the knife blade positioned between them, floating on top of the fabric. This arrangement is called a floating knife coater.

Persistent foams of controlled density lend themselves to knife coating. The add-on is controlled by the gap setting and the density of the foam. After the foam has been metered, the fabric either passes between squeeze rolls or a vacuum slot to break the bubbles and to allow the liquid to penetrate the fabric.

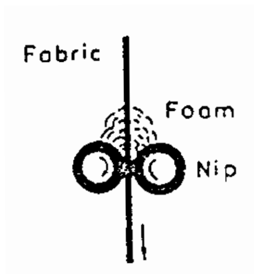
Figure 35. Knife Foam Coater



2. Horizontal Pad

A horizontal pad with a controlled gap between the rollers is a variation of knife coating. Banks of foam can be placed in the crevice between the rollers and the fabric so when the fabric passes downward, the roller will act as the knife allowing a measured amount of foam to pass through. This method applies foam to both sides of the fabric at the same time. Figure 6 illustrates this type of applicator.

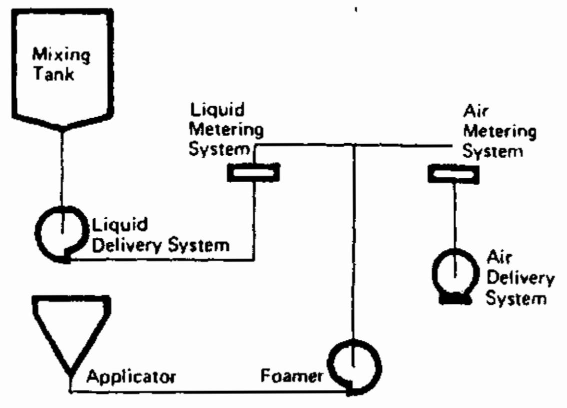
Figure 36. Horizontal Pad Foam Applicator



3. FFT Applicator

Union Carbide and Gaston County developed a low-water finish applicator based on metastable foams. The finish bath and air are continuously metered into a foam generator and the foam is routed through distributing heads directly onto the fabric. Being metastable, the foam immediately breaks on contact with the fabric and the fabric becomes wet with finish solution. Figure 37 shows a schematic of the FFT system. The wet pick-up is regulated by controlling the ratio of liquid feed rate into the foam generator with the cloth speed. By holding the solution feed rate constant, speeding-up or slowing down the cloth speed decreases or increases wet pick-up respectively. Foam density is not a factor affecting wet pick-up by this system. Applicators are designed with two distributing heads so the finish can be applied either to one or both sides of the fabric.

Figure 37. Schematic of FFT System



F. Location of One-sided Applied Finishes

The penetration of a solution from face to back in a one-sided application will depend on several factors. Liquid moves through a fabric by capillary action. The capillaries are the spaces between adjacent fibers in a yarn. If a fabric contains absorptive fibers such as cotton or rayon, a certain amount of liquid will be absorbed within the fiber cross section. This liquid is not available to be transported by the capillaries. The distribution of finish from face to back will be highly dependent on the wet pick-up. For cellulose fabrics, it takes in excess of 40% to get even distribution from front to back. Lower wet pick-ups will cause more of the finish to be located at the face side. This can be an advantage or a disadvantage. For most finishes, it is desirable to have the finish penetrate all of the fibers uniformly throughout the fabric cross-section; however, there are cases where concentrating the finish on one side is advantageous.

If the same amount of liquid is deposited on the face of a polyester fabric as on a cellulosic fabric, more liquid will be found on the back of the polyester fabric than the corresponding cellulosic fabric. The reason for this is that in the polyester fabric, all of the solution resides in the yarn capillaries, all of it can move as capillary liquid; however, in the cellulosic fabric, a certain portion will soak into the interior of the fiber, therefore less is available to migrate as capillary liquid.

II. DRYING AND CURING

Drying is defined as the step where the liquid portion of the solution is evaporated from the fabric. While the concept of drying is simple, in practice it can be the source of unsuspected problems. For drying to take place, the liquid must be converted to vapor and the vapor must be moved away from the surface. The amount of liquid water that evaporates from a given source largely depends on the relative humidity of the air and the volume of air passing over it. Air with low relative humidity has a greater capacity for water vapor than air with a high relative humidity. When the relative humidity nears the saturation value, liquid water is in equilibrium with water vapor and so evaporation is slowed. The absolute amount of water vapor in a volume of air is a function of temperature. For example, at any given relative humidity, the actual amount of water vapor is much greater at high temperatures than at low temperatures.

The rate at which water evaporates from fabric depends on the temperature of the fabric and the volume of air that passes through it. Evaporation of water occurs rapidly at its boiling point. When wet fabric is heated with hot air, (regardless of the air's temperature), the temperature of the fabric will not rise above water's boiling point until all the liquid water is gone. This is true regardless of the fabric's heat source. As water evaporates, the fabric is cooled by evaporative cooling. Some people lose sight of this fact and hold the misconception that wet fabric will be as hot as the air temperature. Some of the factors affecting drying rate are air temperature, relative humidity of drying air and volume of air passing over fabric (air flow).

A. Migration

Chemicals dissolved or suspended in water will move to the point where liquid is converted to vapor. Liquid held in the capillaries is responsible for the phenomenon called migration. If a fabric is heated from one side, the dissolved or suspended chemicals will concentrate at that side. The movement will continue until the moisture level in the fabric is reduced below that required to sustain the filled capillaries. For cellulosic fabrics, this level is about 30 to 40%. To prevent migration, dryers must be designed to evenly remove water from both sides of the fabric. Once the level of moisture is below a critical point, the source of heat becomes less critical.

III. DRYERS AND OVENS

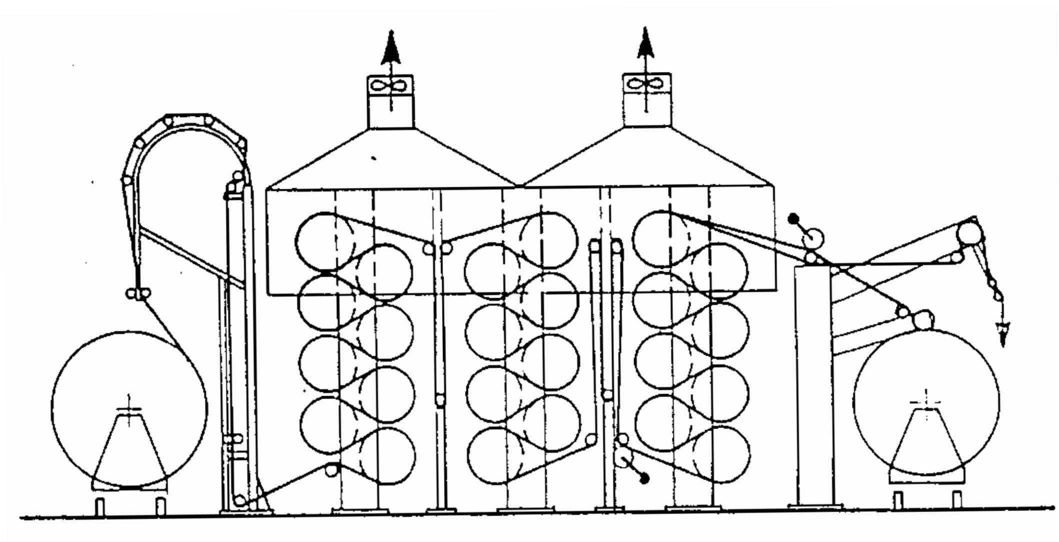
Generally speaking, the same equipment used to dry fabric is also used for curing, provided the equipment is capable of reaching curing temperatures. In many finishing procedures, drying and curing will be divided into two steps. Each step will have its own individual specified conditions. Sometimes however, no delineation between the two is made. Wet fabric enters the oven and cured fabric exits. It is well to remember that fabric temperature will not approach air temperature until all the moisture is gone. In many chemical finishing procedures, the actual fabrics time/temperature relationship is critical in order to activate the chemical reactions. Therefore in one-step drying and curing operations, it is important to know when the fabric is dry so the curing time/temperature relationship is met.

The type of dryer used will affect fabric properties. For example, some fabrics will develop a surface sheen when in contact with heated surfaces, some will shrink unless the fabric is restrained and tension can cause the fabric to become stiff. Additionally tensions can distort fragile fabrics. Choosing the right equipment to handle the fabric is an important matter when one is trying to create specific fabric properties.

A. Dry Cans

The simplest way to dry fabrics is by contacting the fabric with heated surfaces. Fabrics can be dried by continuously running them over a series of large diameter, heated cylinders (cans). By vertically stacking the cans, a lot of heated area can be created with little floor space. Steam, hot oil, electricity and gas flames can be the source of heat for these cans. Most often the cans are heated with high pressure steam. Fabrics dried this way will be under tension in the warp direction. Little warp shrinkage occurs during drying. The fabrics are also somewhat restrained in the filling direction giving some measure of width control.

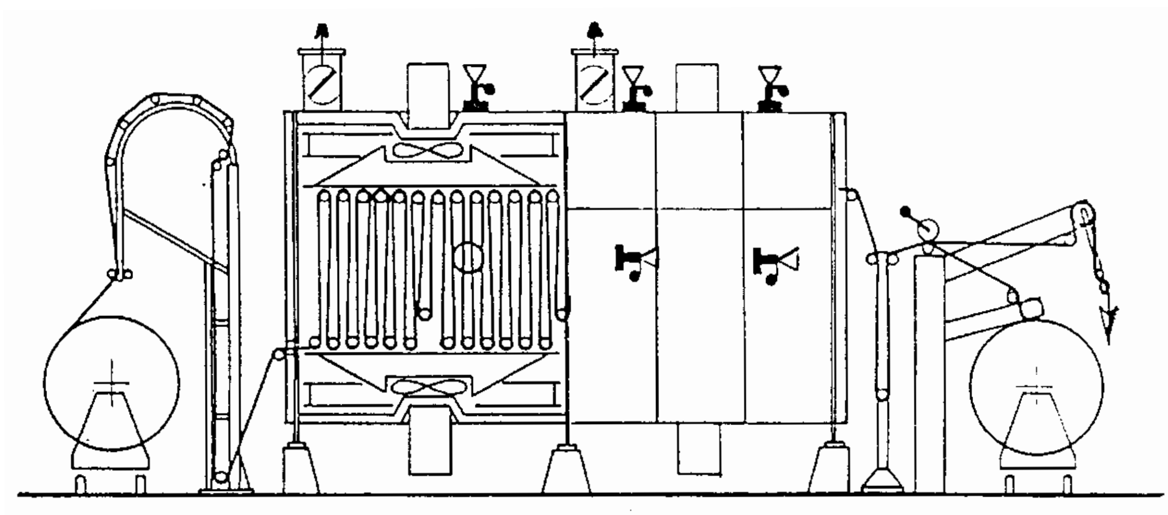
Figure 38. Stacked Drying Cans



B. Roller.Ovens

Roller ovens consist of a series of stationary rollers stacked vertically in a chamber. Fabric enters at one end and passes from the upper roller to the lower roller, threading its way through the chamber to exit out the other end. Air is circulated past the open sheets formed by the alternating pair of upper and lower roller. This allows the fabric to be dried from both sides at the same time. The tensions on the fabric are similar to dry cans, the major difference is that fabric-to-metal surface contact is minimal and water can evaporate from both sides of the fabric simultaneously. Figure 10 shows a two section hot flue, roller oven. Each section can be heated to different temperatures so this arrangement would allow for lower temperature drying zone followed by a higher temperature curing zone.

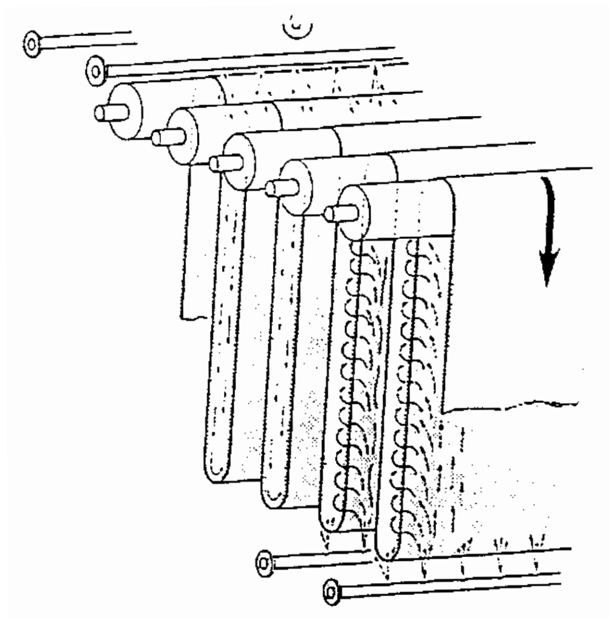
Figure 10. Two Section Roller Oven



C. Loop Ovens

Loop ovens differ from roller ovens in that the rollers move horizontally from the entry side of the chamber to the exit side carrying a loop of fabric along the way. The loop is formed by forcing the fabric between adjacent rollers (sometimes called sticks). The ends of the sticks are attached to a rotating mechanism that constantly propels them through the chamber. Individual loops are continuously being formed at the fabric entry end and removed at the exit end. Hot air circulates through the chamber and the loops are free to flap around as they dry (see figure 11).Fabrics dry in a relaxed state. The fabric is free to shrink so residual shrinkage is lower. Flexing action in the loop oven keeps the fabric from becoming stiff.

Figure 40. Loop Formation over "Sticks"

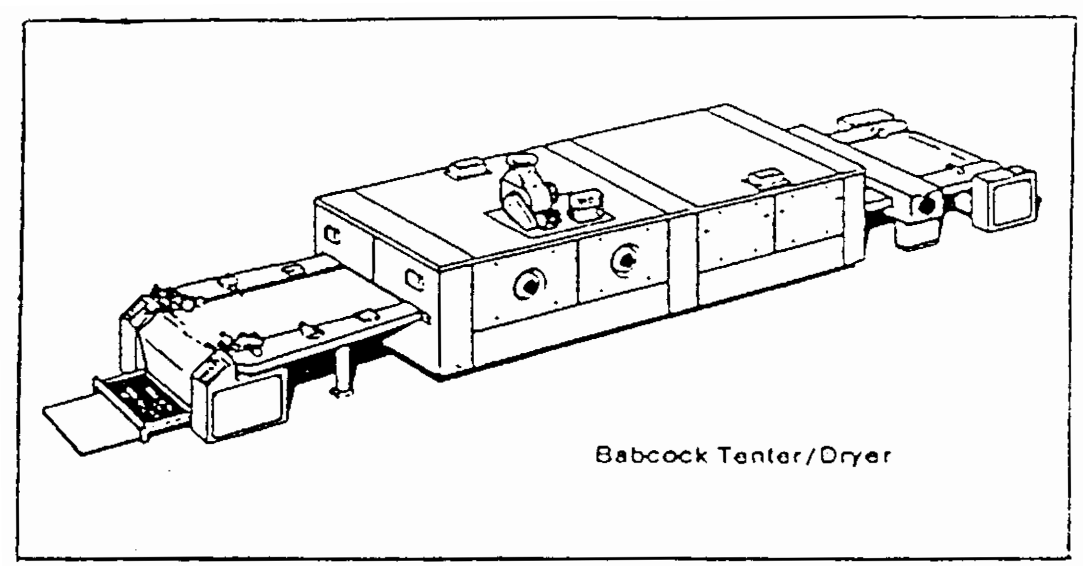


D. TENTER FRAMES

A tenter is a fabric transport device that simultaneously grasps fabric at both selvages and continuously carries it from one point to another. Two endless chains equipped with either clips or pins grasp the selvages and move in synchrony, carrying the fabric between them. The width between the two chains can be automatically adjusted by means of a motor driven screw. The entry end is equipped with edge sensors which signals the screw to move the chains in or out to assure that the edges have been engaged. The width along the length of the chain can be varied by additional independently driven screws located downstream. Sections of the chain can be set to different widths. For example, the width may start out narrow and be pulled out at a subsequent section to make it wider, or it may be set narrower and allowed to shrink. A tenter is the best method of handling fabrics that require precise width control. The tenter also has provision for length control. The fabric either can be stretched or overfed as it enters onto the pins or clips. Many fabrics are sold by the linear yard so as long as the shrinkage requirements are met, stretching is a method of increasing yardage yield. Pin tenters allows for just the opposite to be done; wet fabric can be overfed onto the pins by a separate drive mechanism. The fabric will shrink when it enters in the heated zones. The net effect is to impart low d residual shrinkage at the expense of reduced yardage yield. Overfeeding is a mechanical method imparting low residual shrinkage.

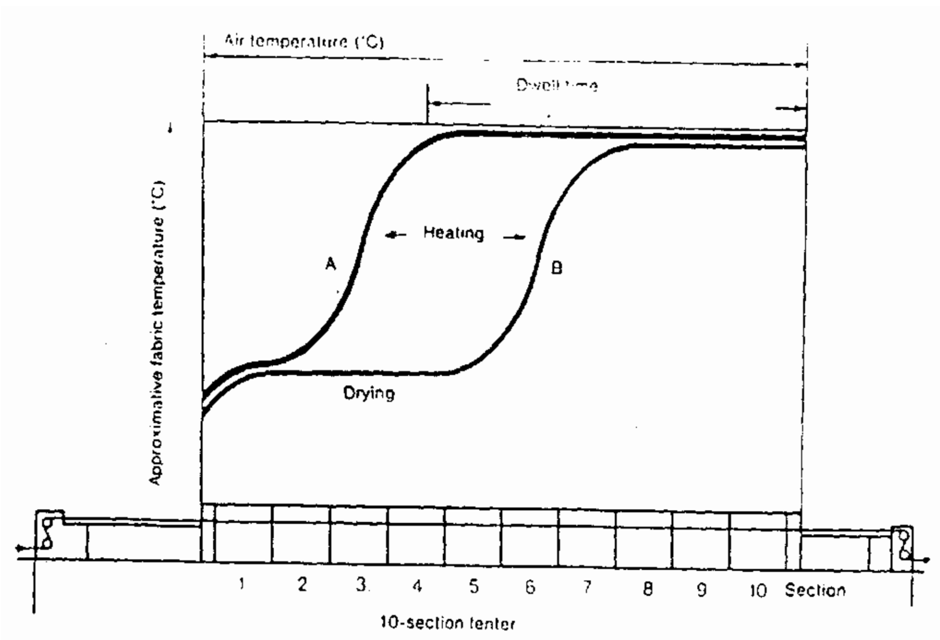
Heating of the fabric occurs when the fabric enters the heated zones. Most tenters are equipped with hot air distribution heads that blow directly onto the top and bottom of the fabric. Either slots or tubes direct the air onto the fabric. Air is directly heated by a gas flame and some of the air is recirculated through the burner while some is exhausted out the stacks. Figure 41 shows a diagram of a typical tenter frame.

Figure 12. Tenter Frame



The heating section of a tenter frame also can be broken down into heating zones. The temperature in each zone can be independently set to profile any drying and curing conditions desired. Figure 42 illustrates the fabric temperature profiles when wet fabrics travel through a ten section tenter frame. Curve A is the profile seen by a fabric when the frame is run at slow speed. Water evaporates quickly after the wet fabric enters the first section. As soon as all the water is gone, fabric temperature reaches the temperature of the heated air. The time it takes to travel from this point to the exit end is the actual time the fabric is exposed to the higher temperature. Curve B represents the temperature profile when the frame is speeded up. Note that it took longer to dry the fabric so the time the fabric was exposed to the higher temperature was less. In both cases, the air temperatures in each section was unchanged, only the fabric speed changed. The implication of this is that knowledge of the fabric temperature profile is a must if time of cure influences the properties of finished fabrics (which it does for many finishes). All older frames have air temperature indicators located along the inside of the frame. However this alone will not insure proper control of the drying and curing process. Some modern frames are equipped with fabric temperature sensors located along the length of the frame as a better way of controlling the process. By knowing the point within the frame when the fabric is dry, the frame could be programmed to give the time necessary for curing to take place. For a light weight fabric, the frame could be speeded up and the chances of overcuring eliminated. Conversely the frame should be slowed down for a heavy fabric that takes longer to dry otherwise the time of cure will be much less.

Figure 42. Effect of Range Speed on Fabric Temperature Profile



E. OTHER DRYERS

There are other types of dryers, each designed for a specific purpose. For example,

- Drum and conveyer dryers for knit goods. These accommodate the need to not put excessive tensions in either direction of the fabric.

- Tumble dryers - used to develop fabric texture.

- Combination heated cylinder/forced hot air dryers - designed for faster heat up of woven goods.

A detailed description of all types of dryers is beyond the scope of this manuscript.

IV. REFERENCES