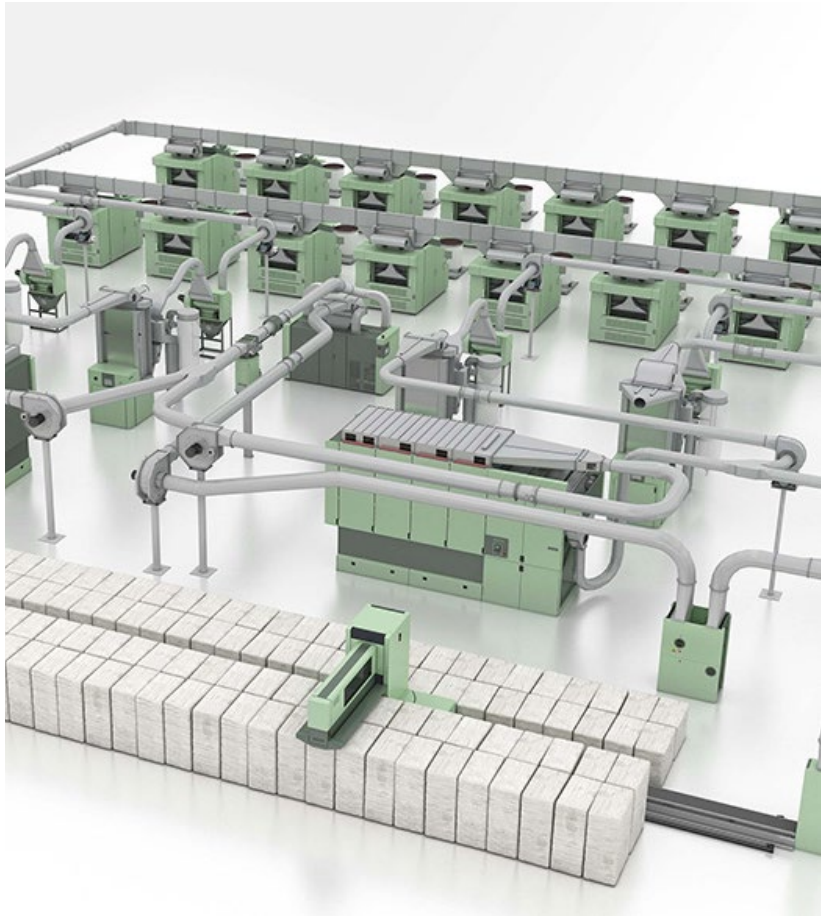
Principles of Textiles

- **Agenda:**
  - Fibers
  - Fiber and Yarn Processing
  - Types of Fabric Formation
  - Dyeing and Finishing



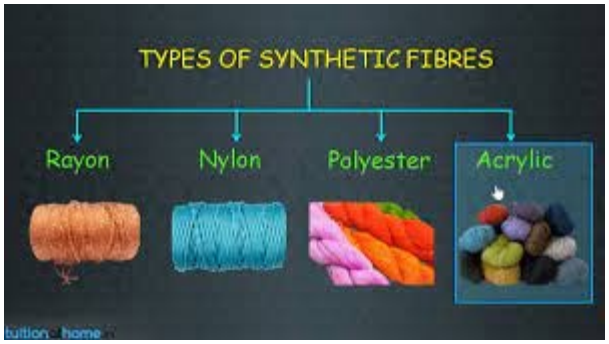
Natural Fibers





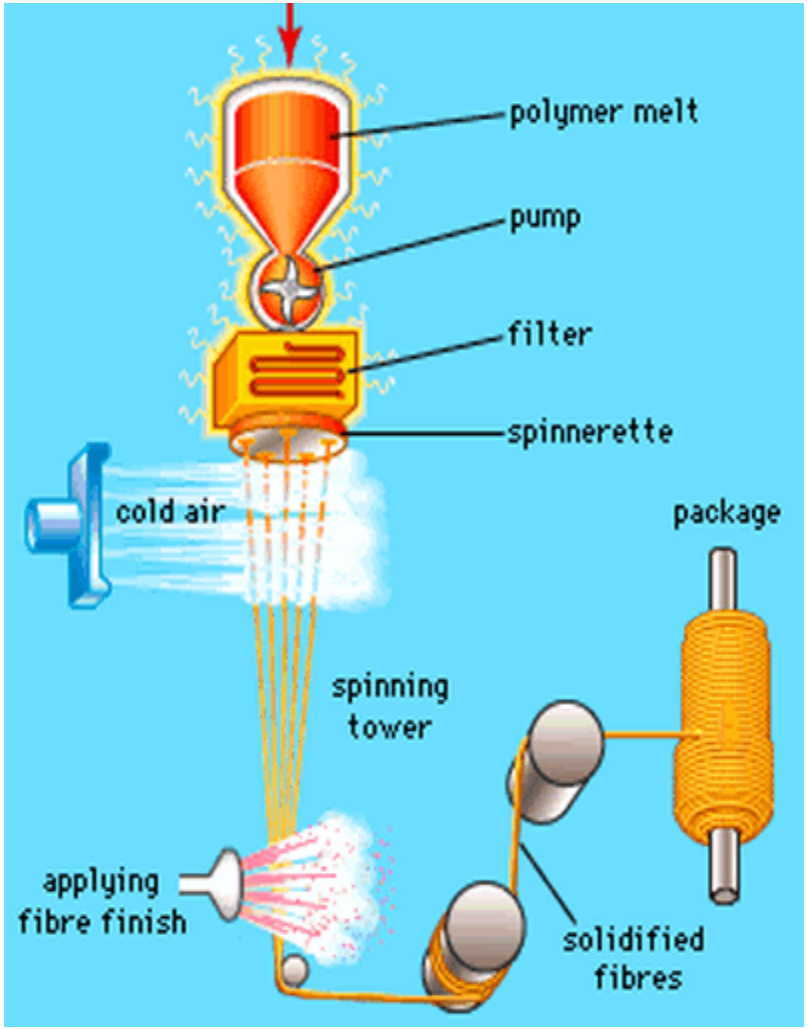
- Animal: Silk, wool, mohair, cashmere, alpaca
- Plant: Cotton, flax, bamboo, jute, hemp
- Short Staple Fibers: anything under 2.0”
- Long Staple Fibers: anything above 2.0”
- Pros: Soft cool hand, comfort, organic
- Cons: Low strength, wrinkle easily, can be damaged by moths/insects

Man-made Synthetic Fibers



- Chemical polymer base
- Manufactured on engineered equipment
- Products: Polyester, nylon, rayon, acetate, acrylic, spandex, olefin
- Fiber lengths: Short staple to “endless” filament
- Pros: High strength, can be engineered to achieve desired performance
- Cons: Can be uncomfortable --- low moisture absorbency, environmental pollution

Polymerization Process

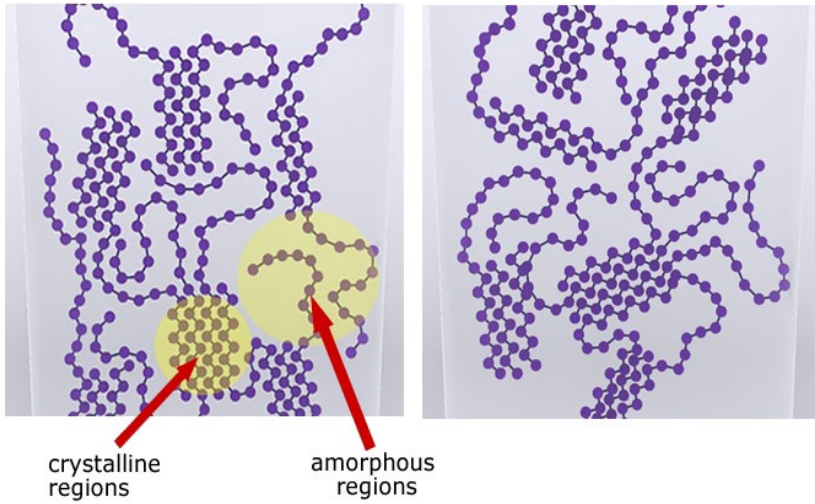


Polymerization

Polymerization is the linking of many small molecules (monomers) to form a long, chain-like molecule (polymer).

Monomer: One repeating unit

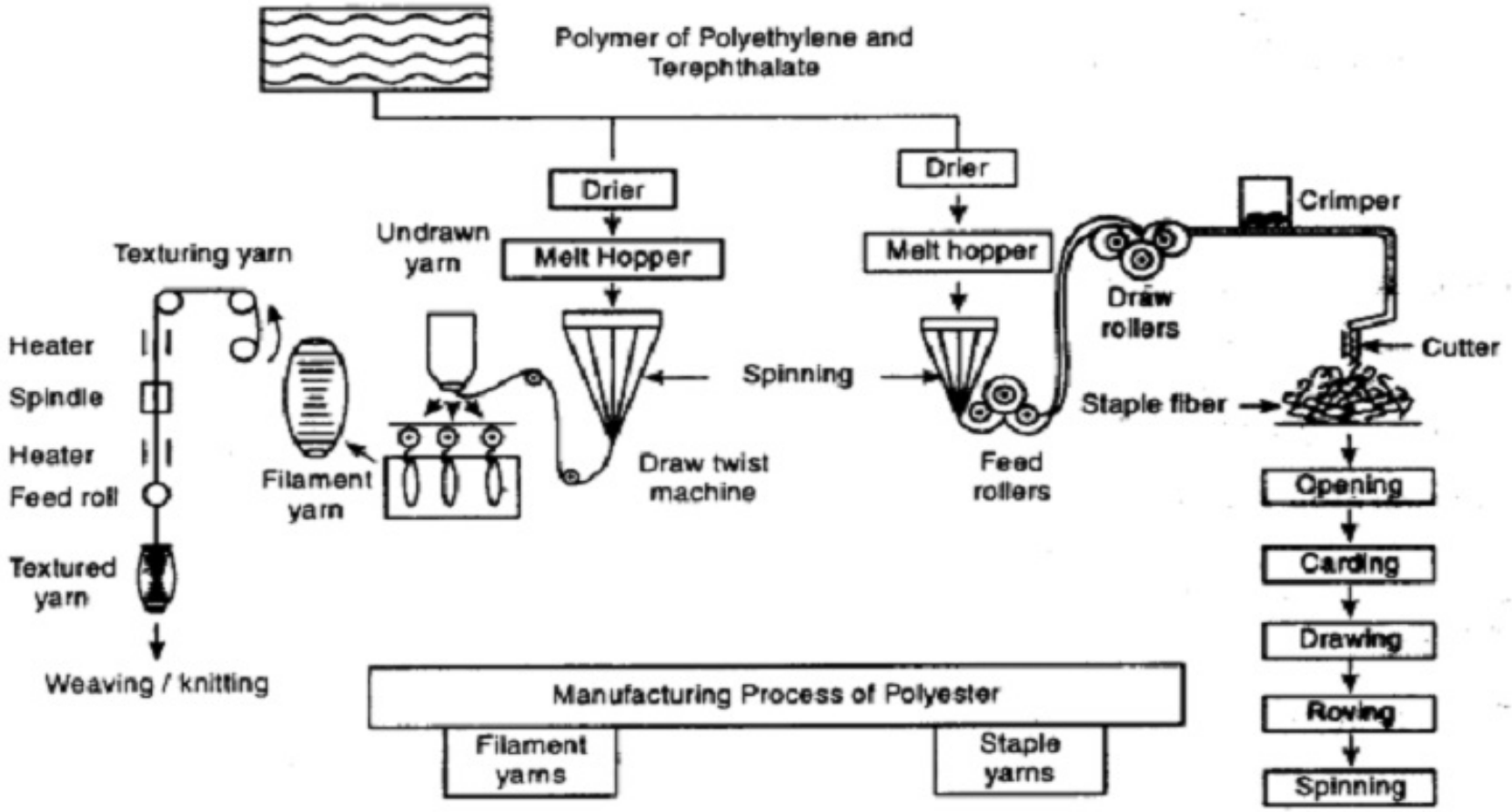
Polymer: Multiple monomers linked together



Fiber Properties Depend On:

- Chemical composition of the polymer
- Arrangement of polymer molecules

Converting Continuous Filament to Staple Fiber



Continuous Filament/Staple Tow Manufacturing



Function of Crimps/Inch – Synthetic Fibers

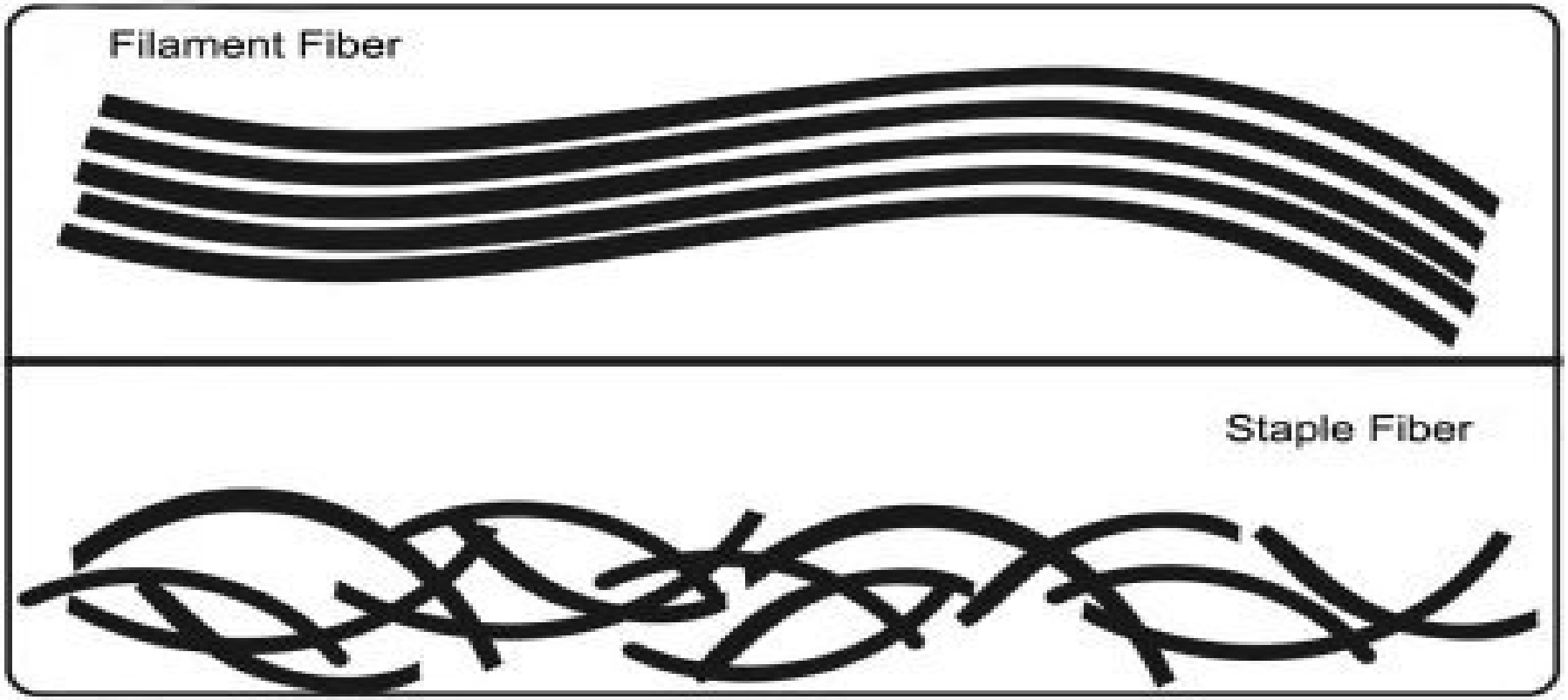


Crimps/inch in synthetic fibers such as polyester, refers to the waves or bends along the length of the fiber. For good carding conditions, the range is usually10-12 crimps/inch. These bends effect how the fibers interlock and catch onto one another and behave during the carding process, as follows:

- Prevents fibers from lying flat
- Regulates ease of fiber drafting
- Facilitates greater web uniformity

Converting Continuous Filament to Staple Fiber

Continuous filaments can be cut and crimped into any length to make short or long staple fibers.



Continuous Filament to Staple Fiber



Textile Processes

- Bale Lay-Down
- Opening & Cleaning
- Carding
- Drawing
- Roving
- Spinning
- Winding
- Fabric Formation

Yarn Count/Numbering Systems

UNDERSTANDING YARN COUNT

THE BACKBONE OF TEXTILE FINENESS

INDIRECT COUNT

- Used in cotton, linen, wool
- Higher count = **FINER** yarn

  e.g. Ne 40 is finer than Ne 20

DIRECT COUNT

- Used in synthetics like polyester
- Higher count = **COARSER** yarn

  e.g. 100 denier is thicker than 30 denier

SYSTEM	USAGE	UNIT	MEANING
Ne	Cotton	Indirect	Higher = finer
Nm	Wool/Linen	Indirect	Higher = finer
Tex	Synthetics	Direct	Higher = thicker
Denier	Synthetics	Direct	Higher = thicker

Sewing Thread Numbering System

Tex System is a direct system:

Tex = weight in grams of 1,000 meters of thread

Conversions:

I. **Filament yarns:** **Tex = Denier x 0.111** **Denier = Tex x 9**

II. **Spun yarns (Ne)*: Ne = 590.5 ÷ Tex** **Tex = 590.5 ÷ Ne**

III. **Denier = 5314.9 ÷ Ne** **Ne = 5314.9 ÷ Denier**

Example: A. T90 filament yarn: Tex x 9 = 810 Denier

B. T27 spun yarn: 590.5 ÷ 27 = Ne 21.87/1's

Bale Lay-Down

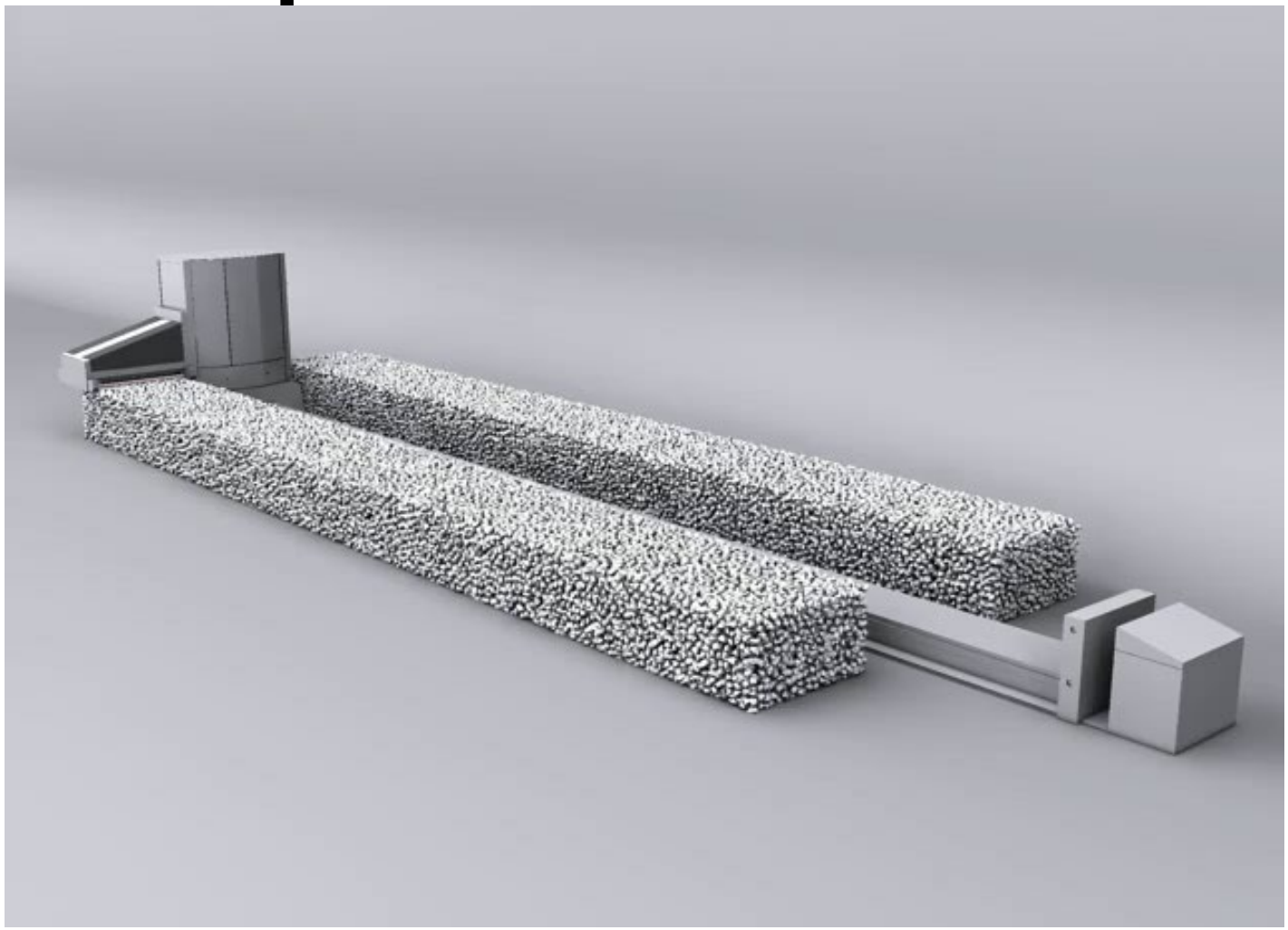
A series of fiber bales are laid down side by side and tufts of fiber are removed from each bale.



Top Feeder Opening Rollers Video



Top Feeder Animation

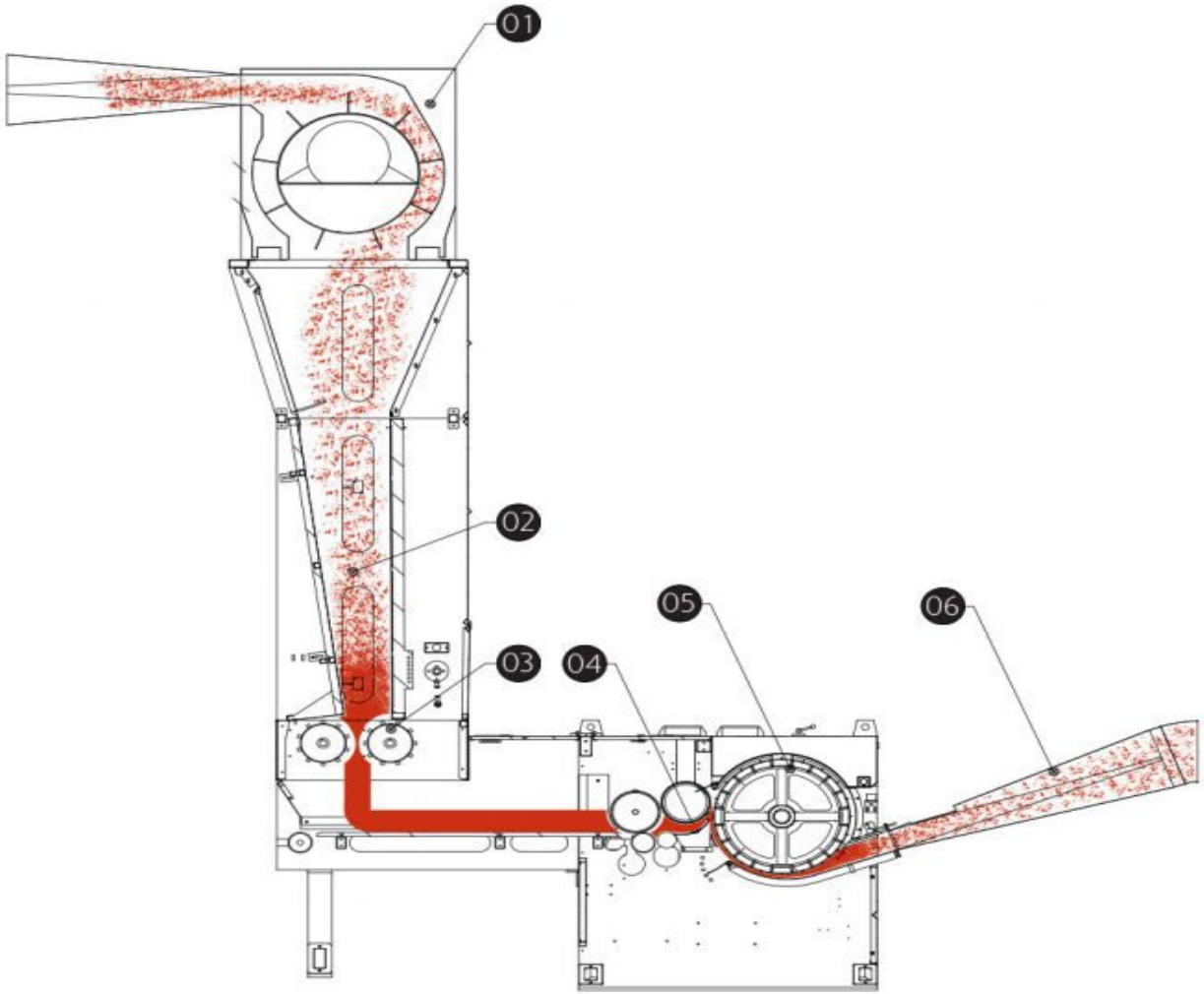


Opening

- Objective: To separate the compressed and matted tufts of staple fiber into small, open and loose fiber sections

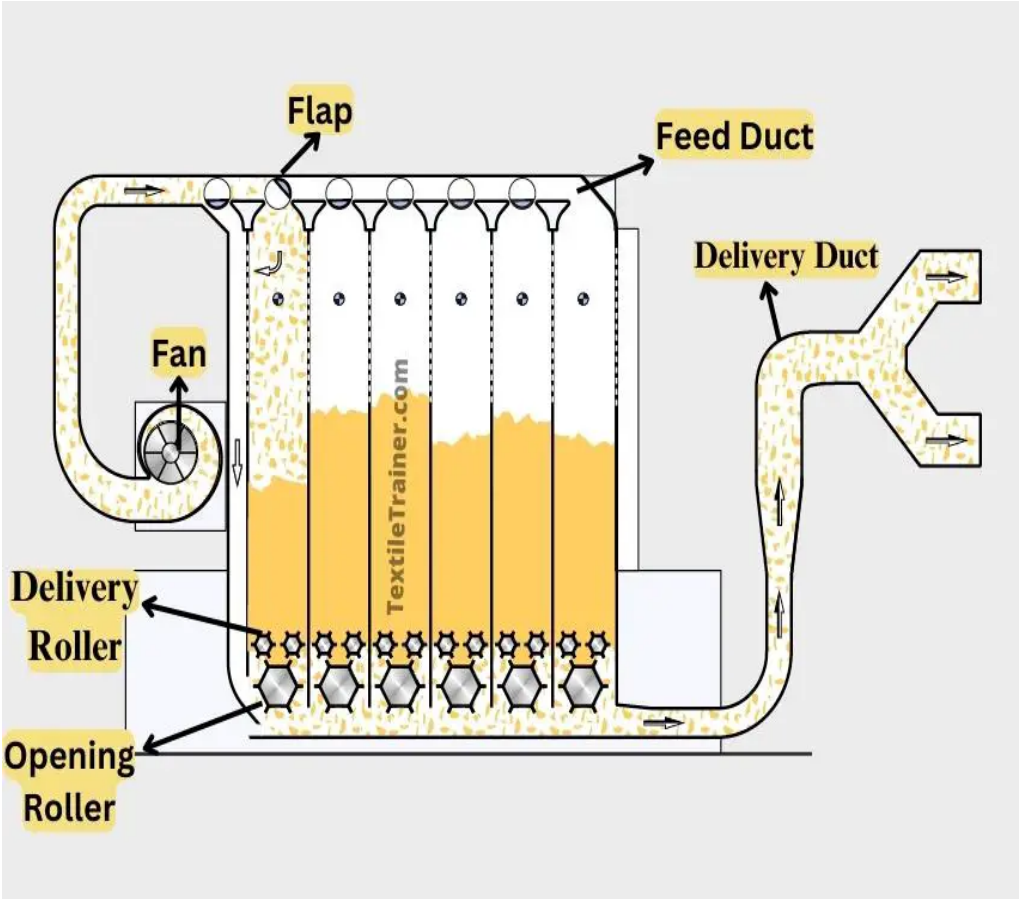


Fine Opener/Cleaner

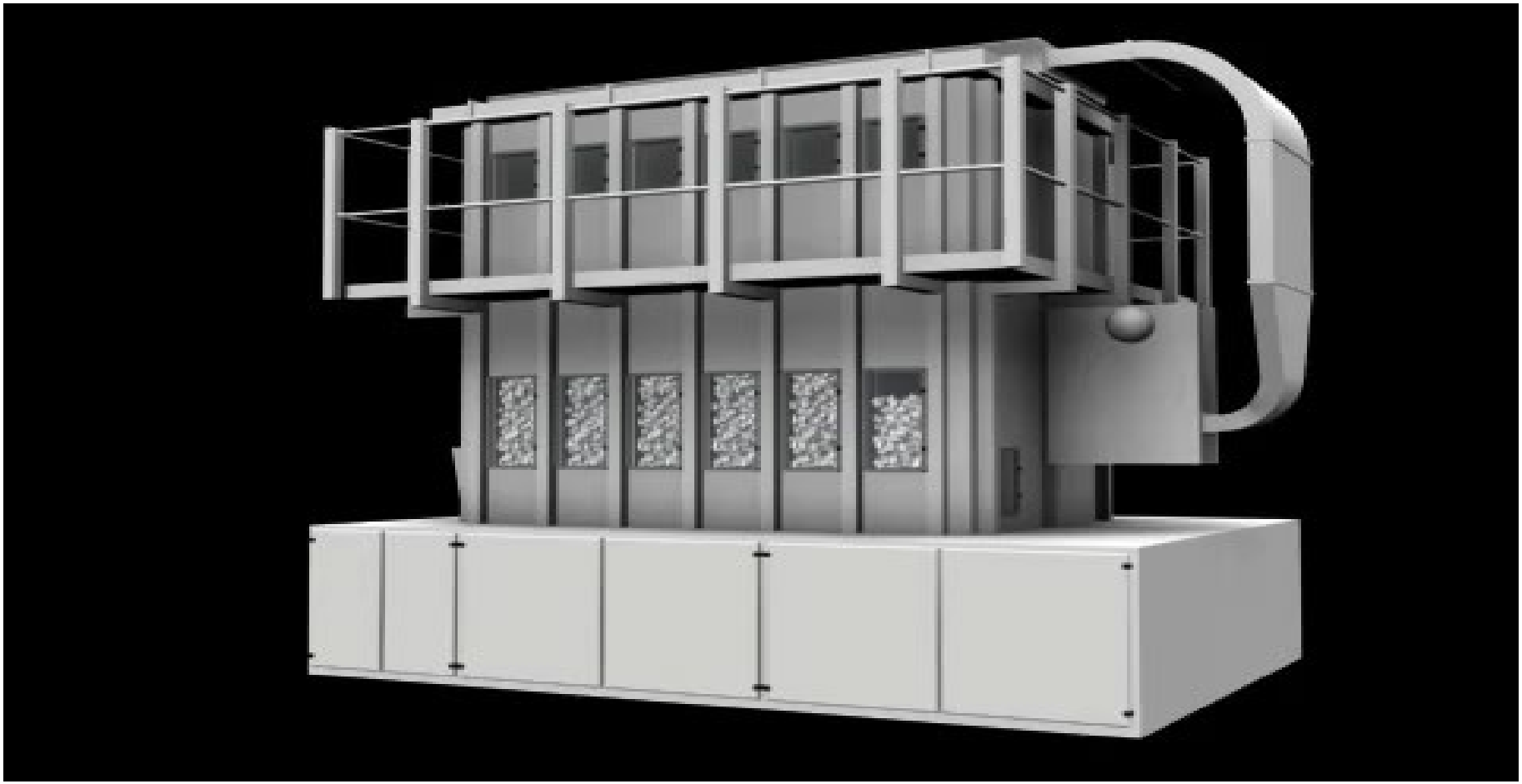


Multi-Mixer

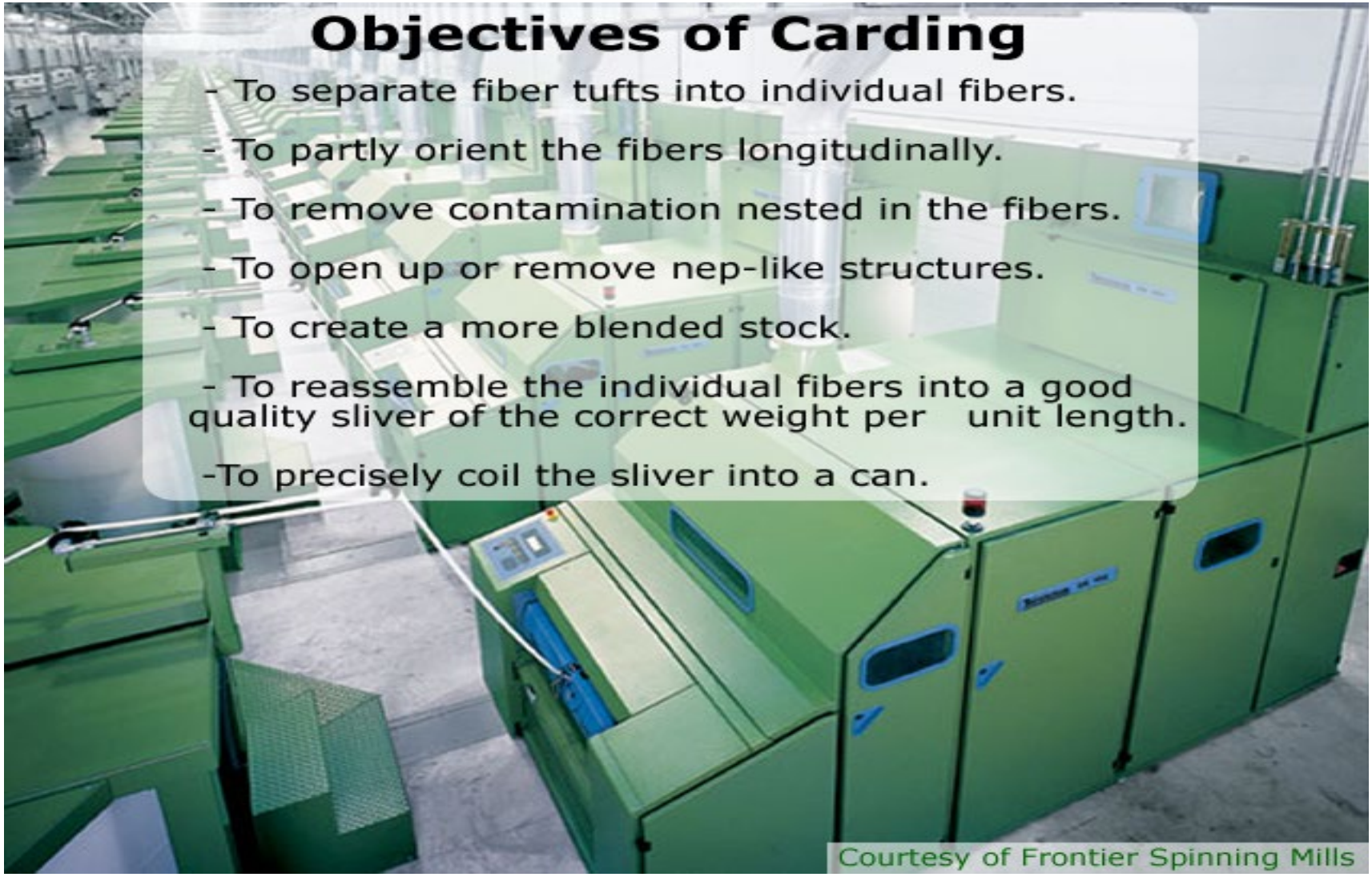
The multi-mixer consists of 6 to 12, individual chambers. It is designed to ensure that a perfect and homogeneous blend is achieved, with maximum homogeneity and a uniform blend of fibers that is reproducible.



Multi-Mixer Blending Machine Animation



Carding


Objectives of Carding
- To separate fiber tufts into individual fibers.
- To partly orient the fibers longitudinally.
- To remove contamination nested in the fibers.
- To open up or remove nep-like structures.
- To create a more blended stock.
- To reassemble the individual fibers into a good quality sliver of the correct weight per unit length.
-To precisely coil the sliver into a can.
Courtesy of Frontier Spinning Mills

Drawing

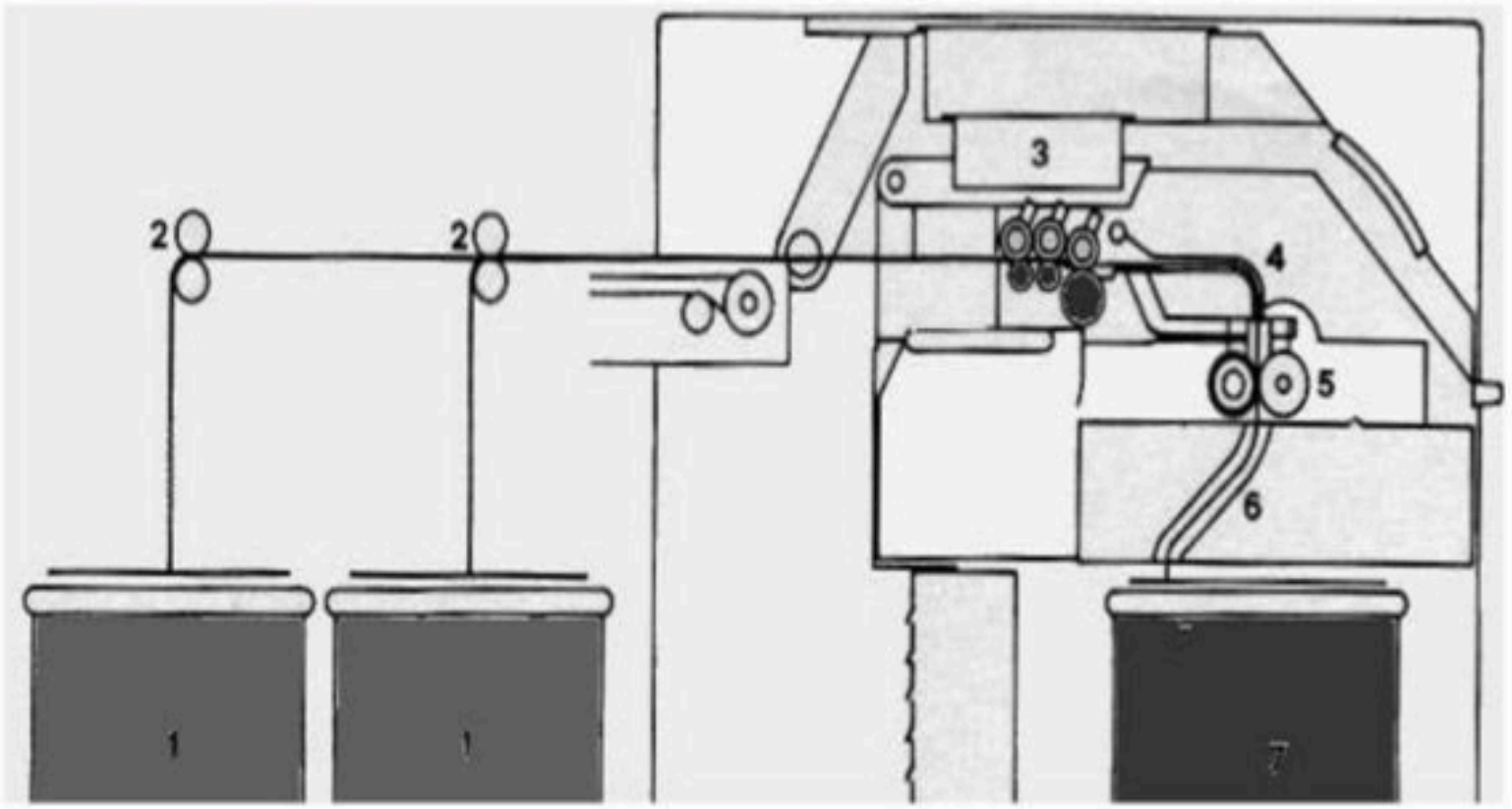
- Objective: To combine 6 to 8 cans of card sliver together to improve sliver weight uniformity, to reduce unevenness and improve fiber alignment, especially when blends are being formulated.
- Note: Sliver weights are measured in grains per yard (7000 grains/lb).





Basic principle Of Drawframe

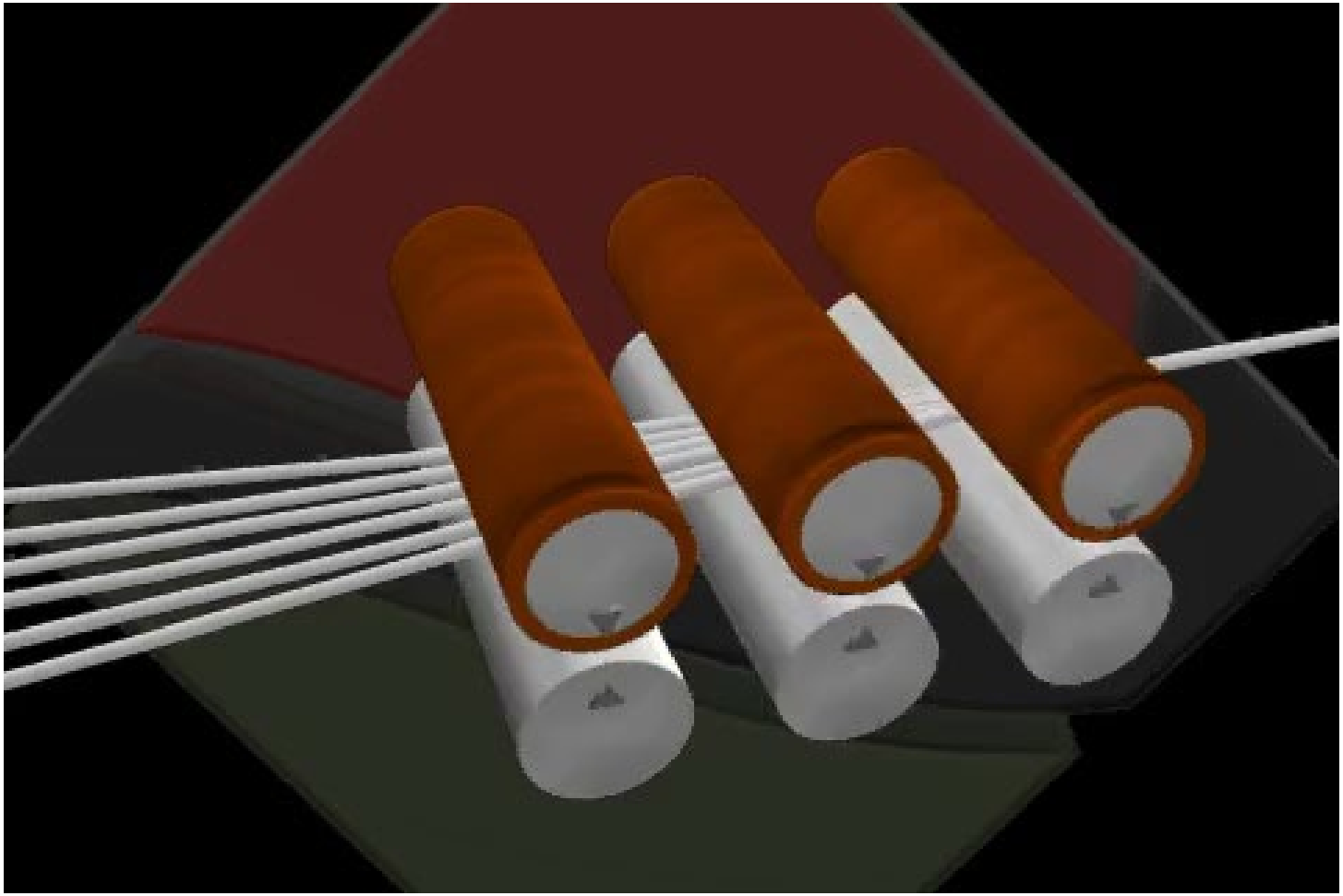
Operating principle:



Drawing Overview Video



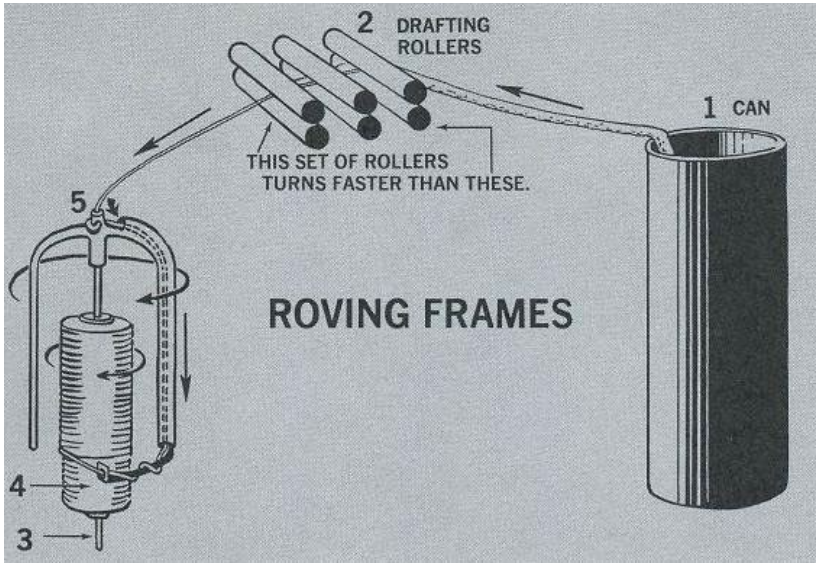
Drafting Rollers Animation



Roving

- Objective : To further align the fibers and reduce the sliver size and weight in preparation for spinning. A small amount of twist is imparted by the rotation of the flyer. The amount of twist is enough for the roving to unwind without breaking or stretching at spinning.

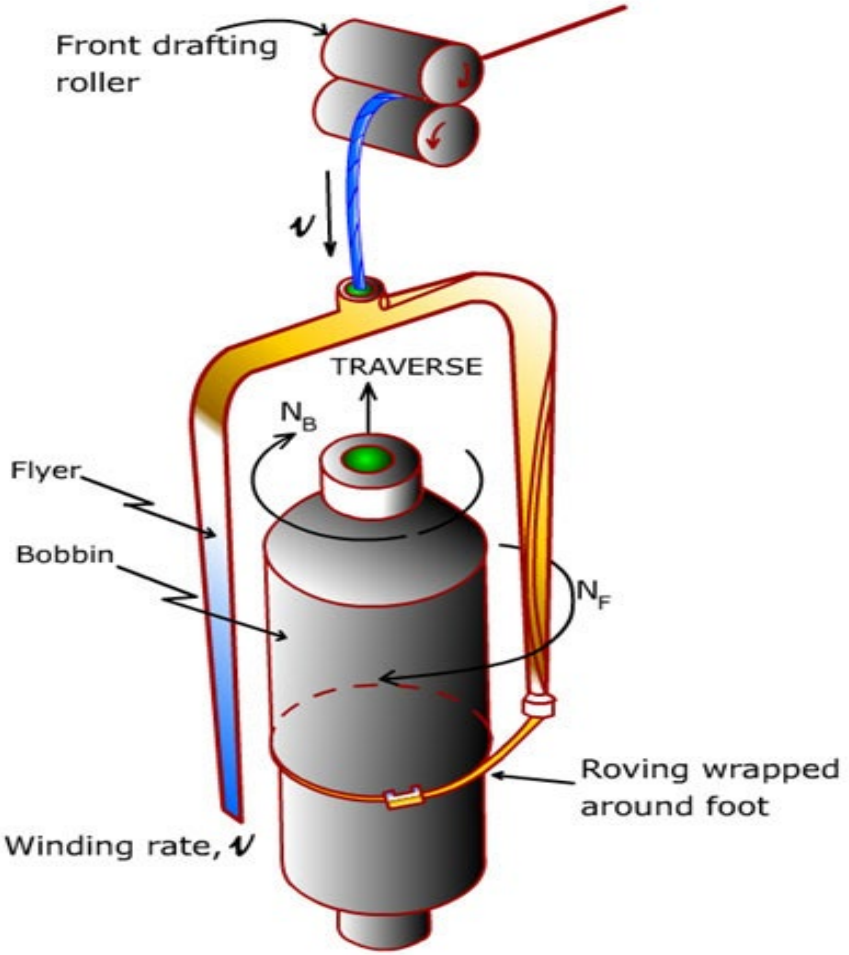




Drafting Rollers Video



Roving Frame Flyer



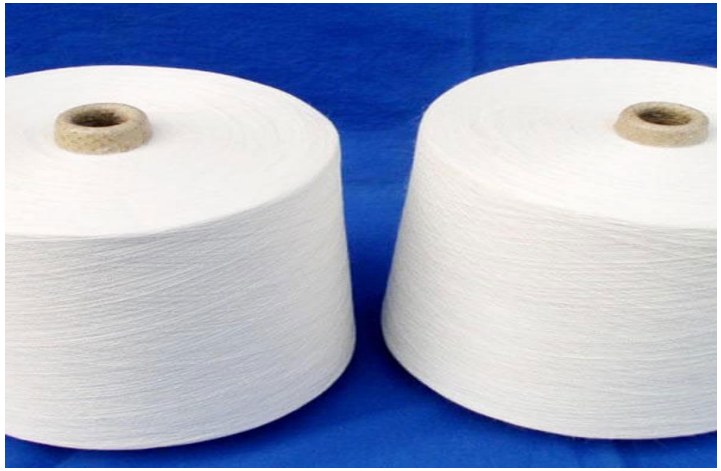
Roving Bobbins Video



Spinning

- Objective: To draw down the roving to the final yarn size, insert twist to hold yarn together and wind up on bobbins. There are three types:

- Ring spinning



- Open end spinning (Rotor spinning)

- Vortex spinning

Ring Spinning



Ring Spinning Draft Zone

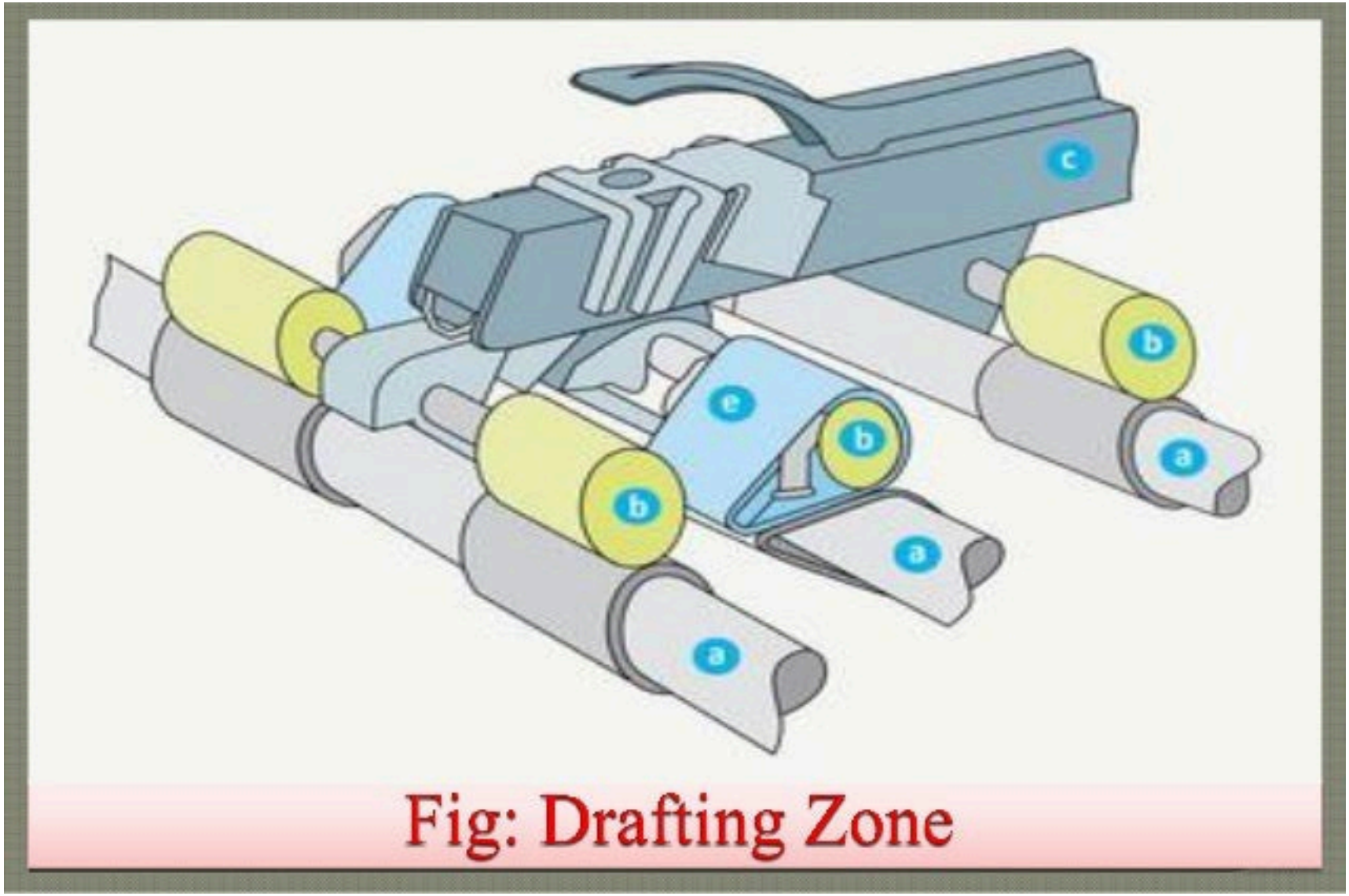
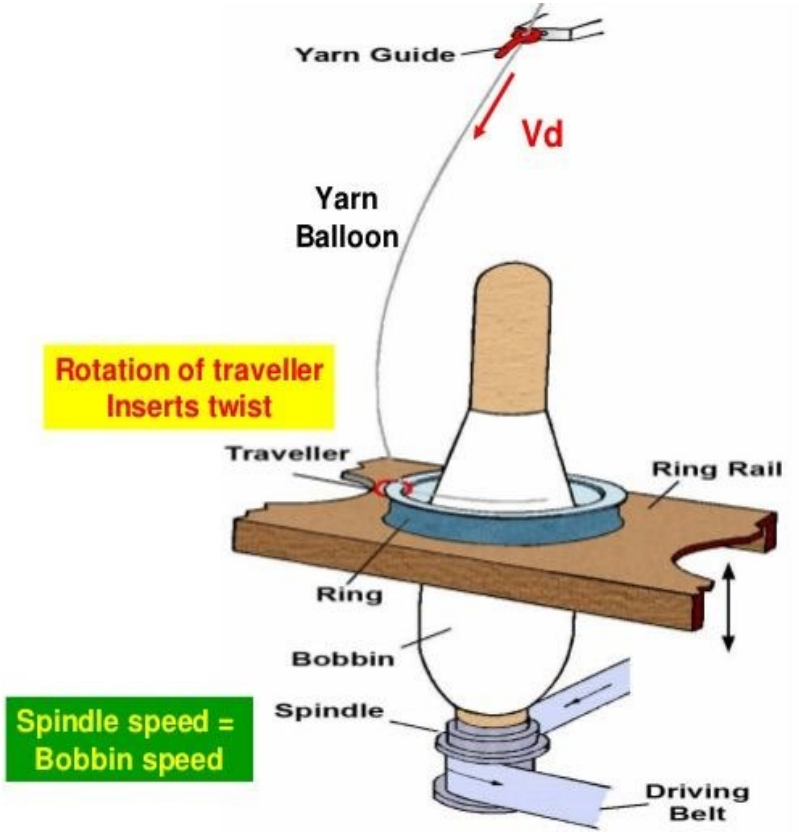


Fig: Drafting Zone

Ring Spinning Machine Components



Ring Spinning - Summary

- **Yarn Counts:** 6/1's to 250/1's
- **Fibers:** Long, Fine & Strong

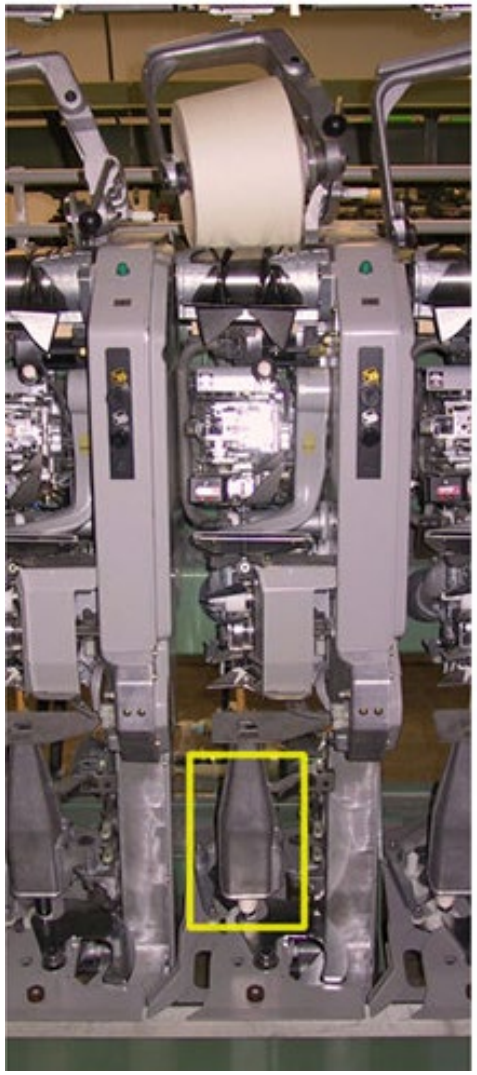
- **Yarn Characteristics:**
- Standard for other yarns.
- True Twist
- Good strength
- Known ring appearance &feel
- Good tear strength in fabric
- Fabric hand is soft and smooth
- Highest cost/lowest production rate
- Yarn evenness is less than OE & MJS



Ring Spun Yarn Winding

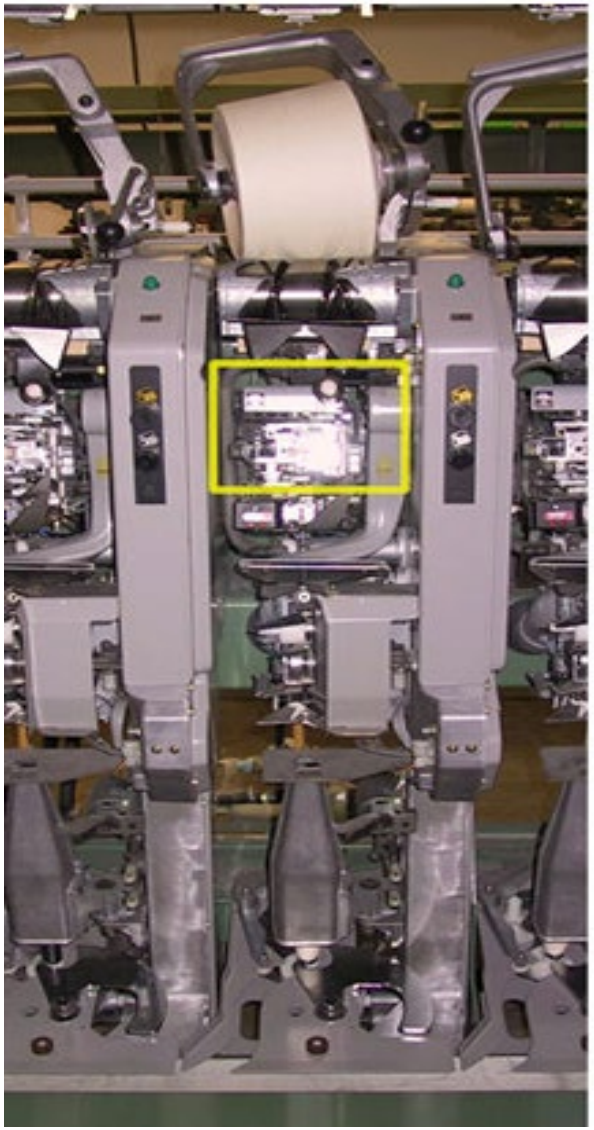


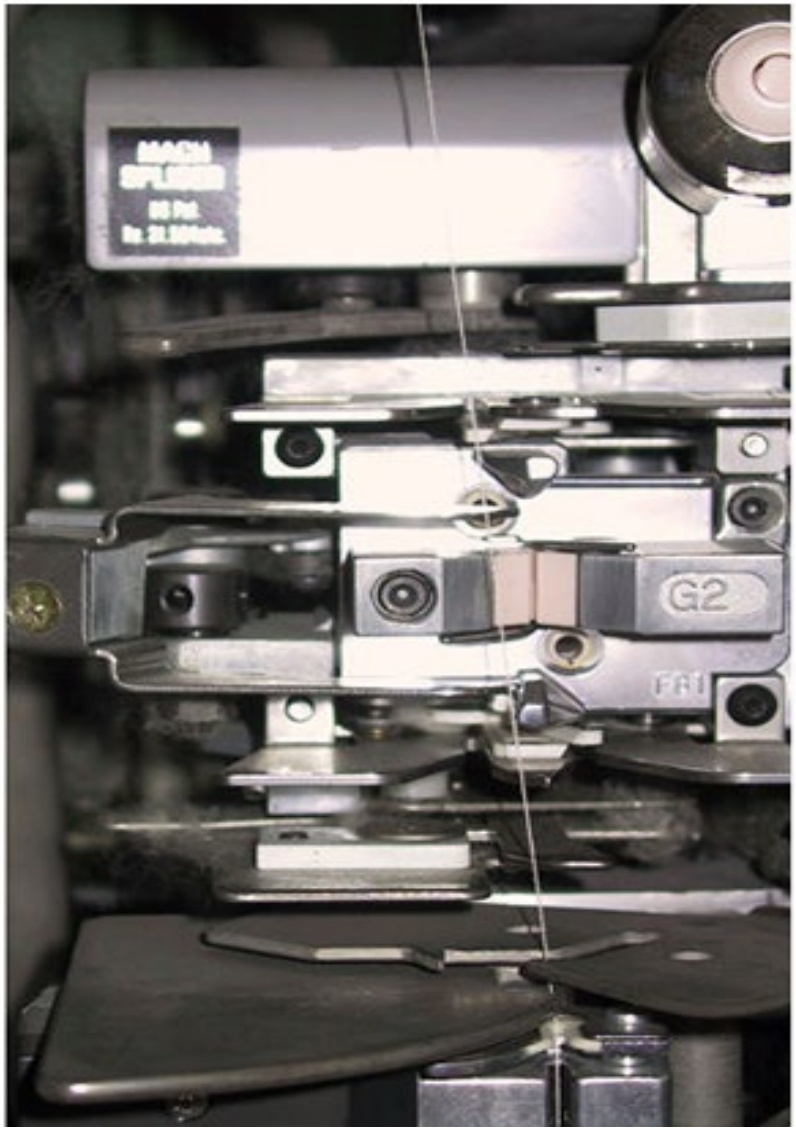
Winder Overview





Winder Air Spicer





End Uses for R.S. Yarns

- All Knits and Fabrics
- Fine Count Sheeting
- Fine Count Shirting
- Upper End Apparel
- Industrial Applications
- High Performance Military Apparel



Open End Spinning (Rotor)



Open End Spinning (Rotor)

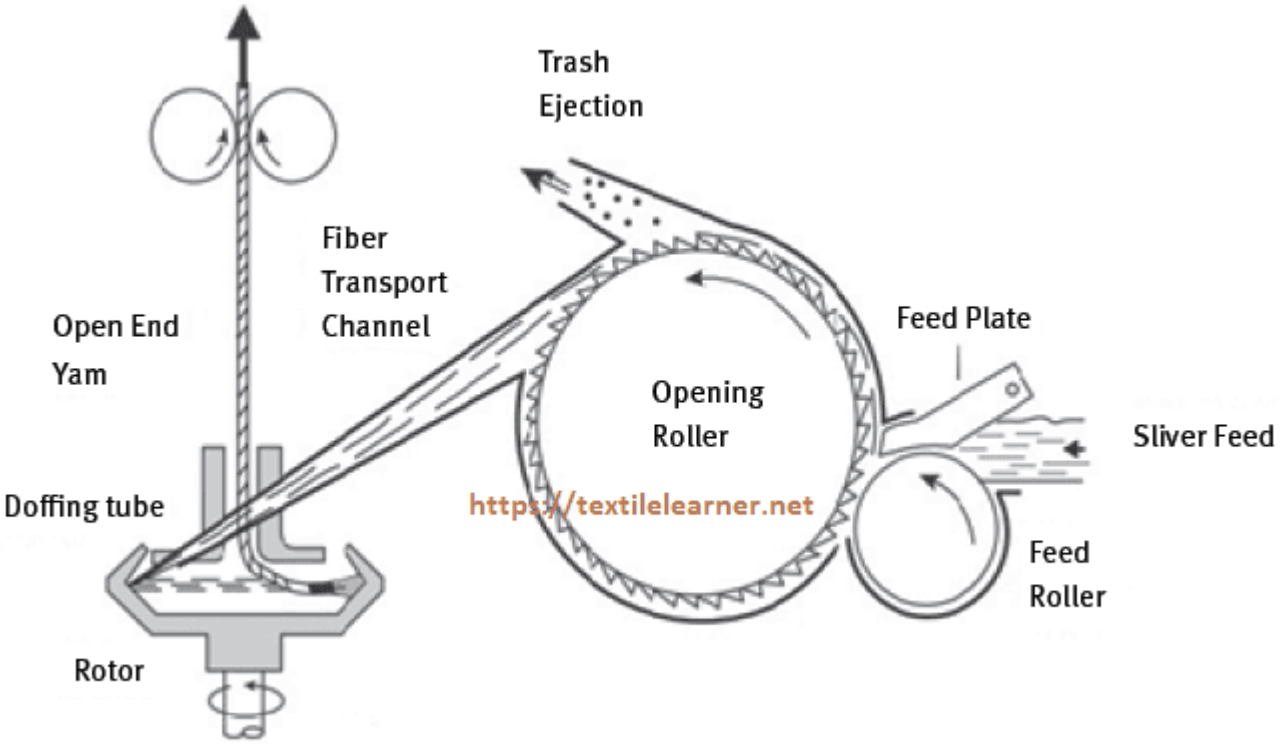
Unlike ring spinning, open end spinning does not require the roving process or an off-site winding process. The yarn is produced from finisher drawing sliver and after the spinning process, electronically cleared and is automatically wound onto a cone/tube with a transfer tail.

The finisher drawing is fed into the spinbox via a feed roll. The fiber in the sliver is opened and individualized by a rotating combing/opening roll, which is equipped with metallic wire, much like a cylinder on a carding machine. The fiber is removed from the combing/opening roll by a vacuum and is directed into a rotating "cup-shaped" device, known as a rotor. As the fibers form into the pre-determined yarn mass, the yarn is pulled out of the rotor by the yarn already wound onto the cone/tube on the individual spinboxes winding unit.

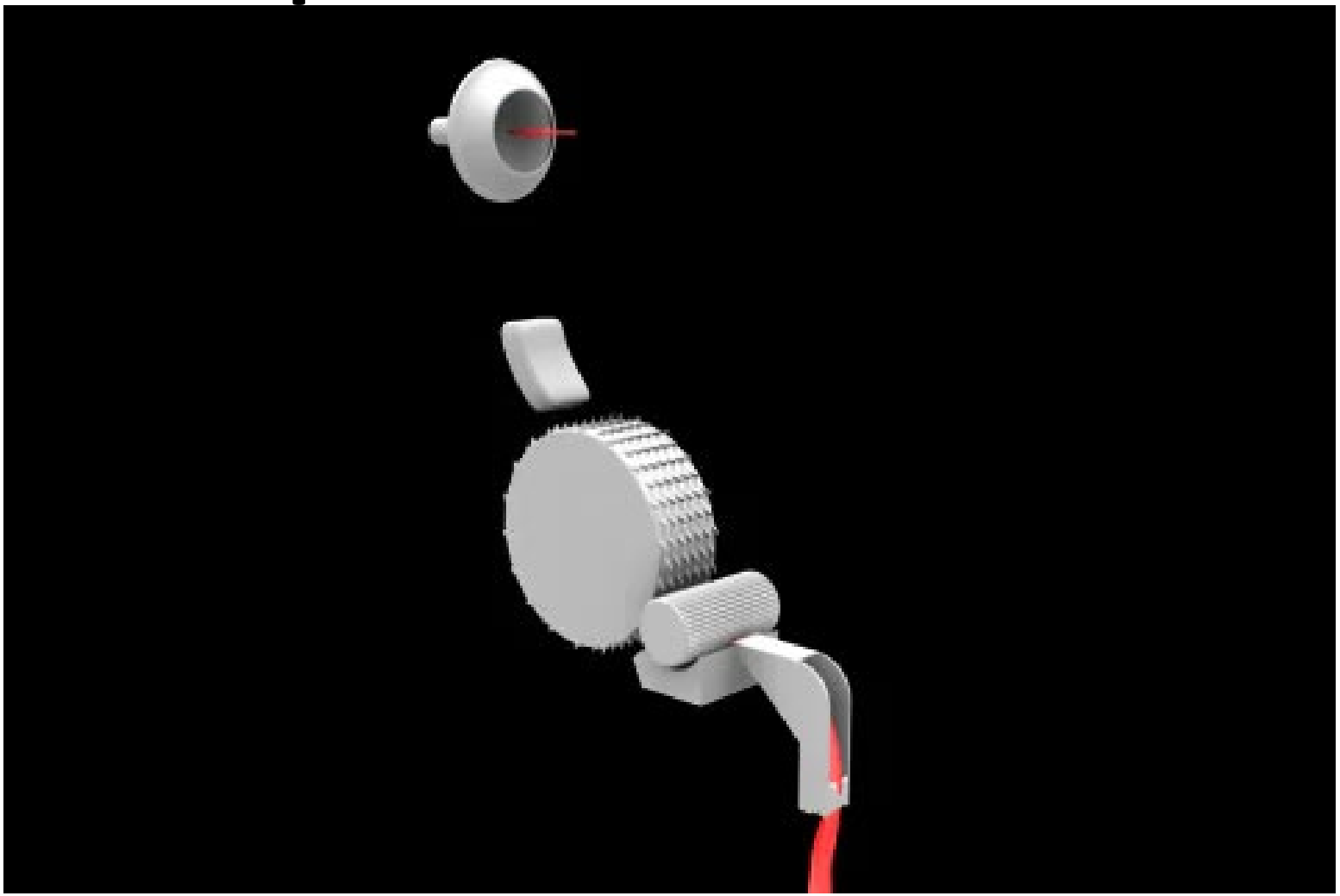
The resulting yarn does not have "real"twist, as does a ring spun yarn. This results in open end yarn being 15-20% weaker than ring spun yarn. However, it is usually more even and has less imperfections.



Open End Spinning (Rotor)



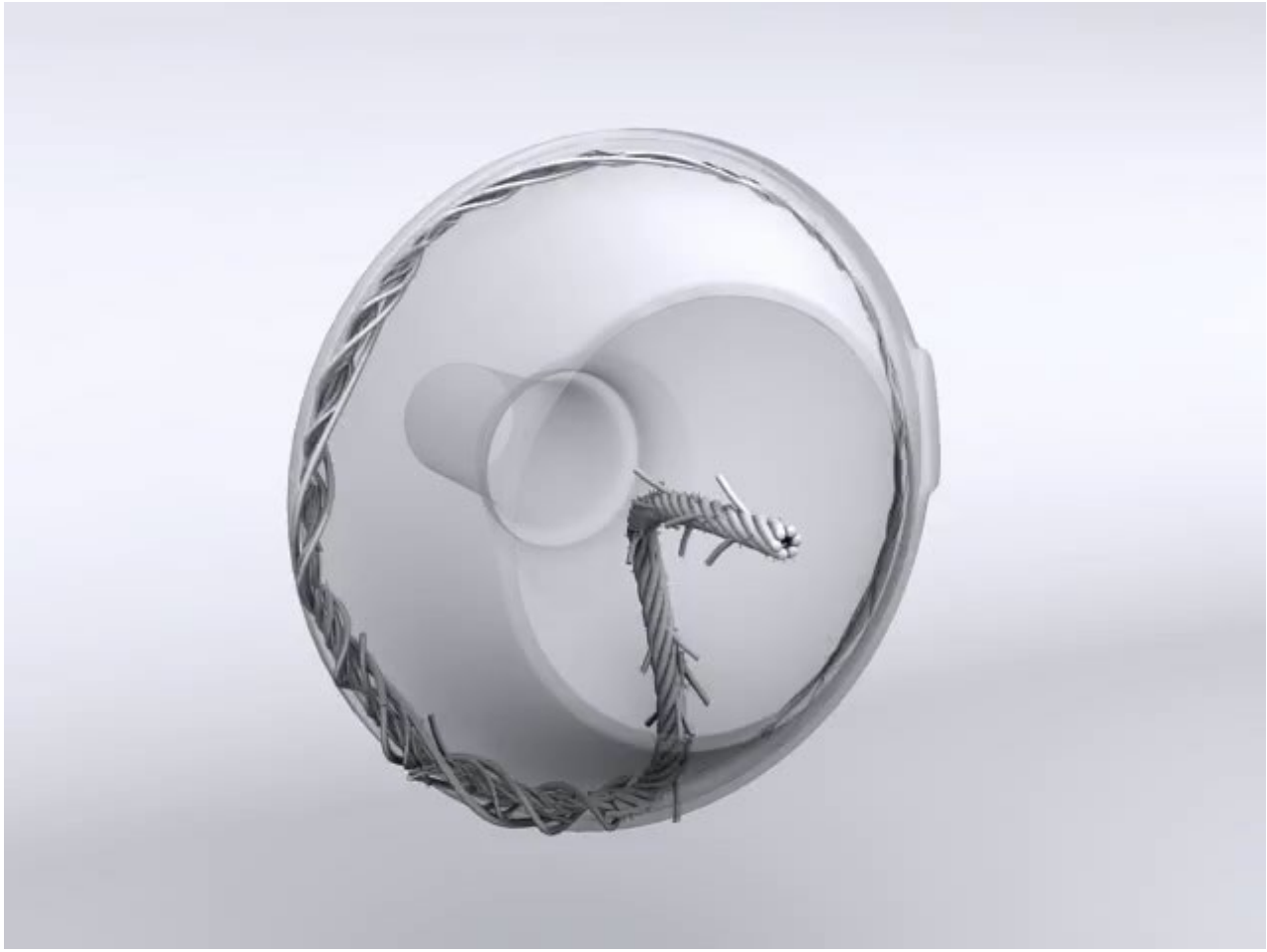
Open End Animation



Open End Spinning Video



Open End Spinning Animation

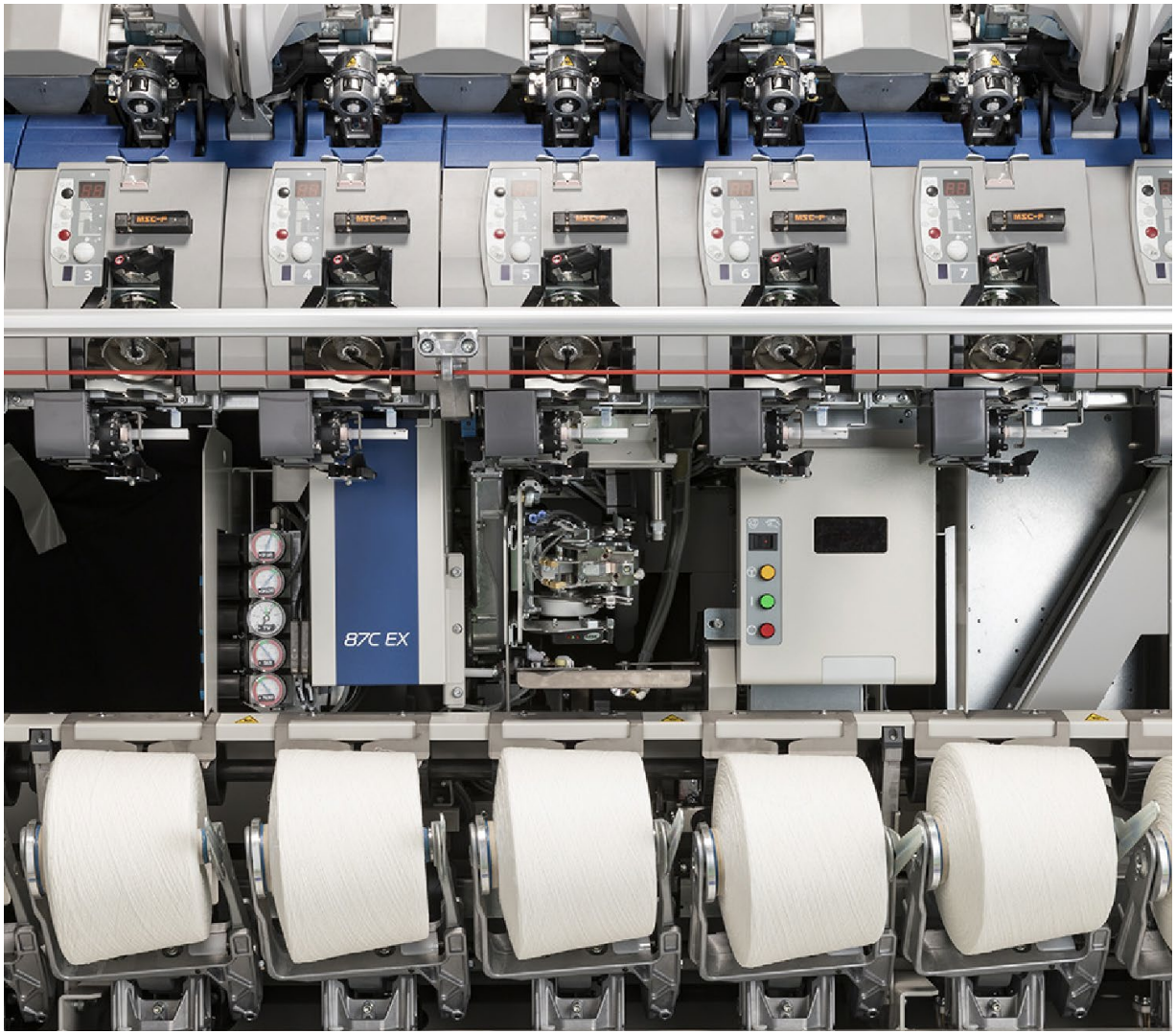


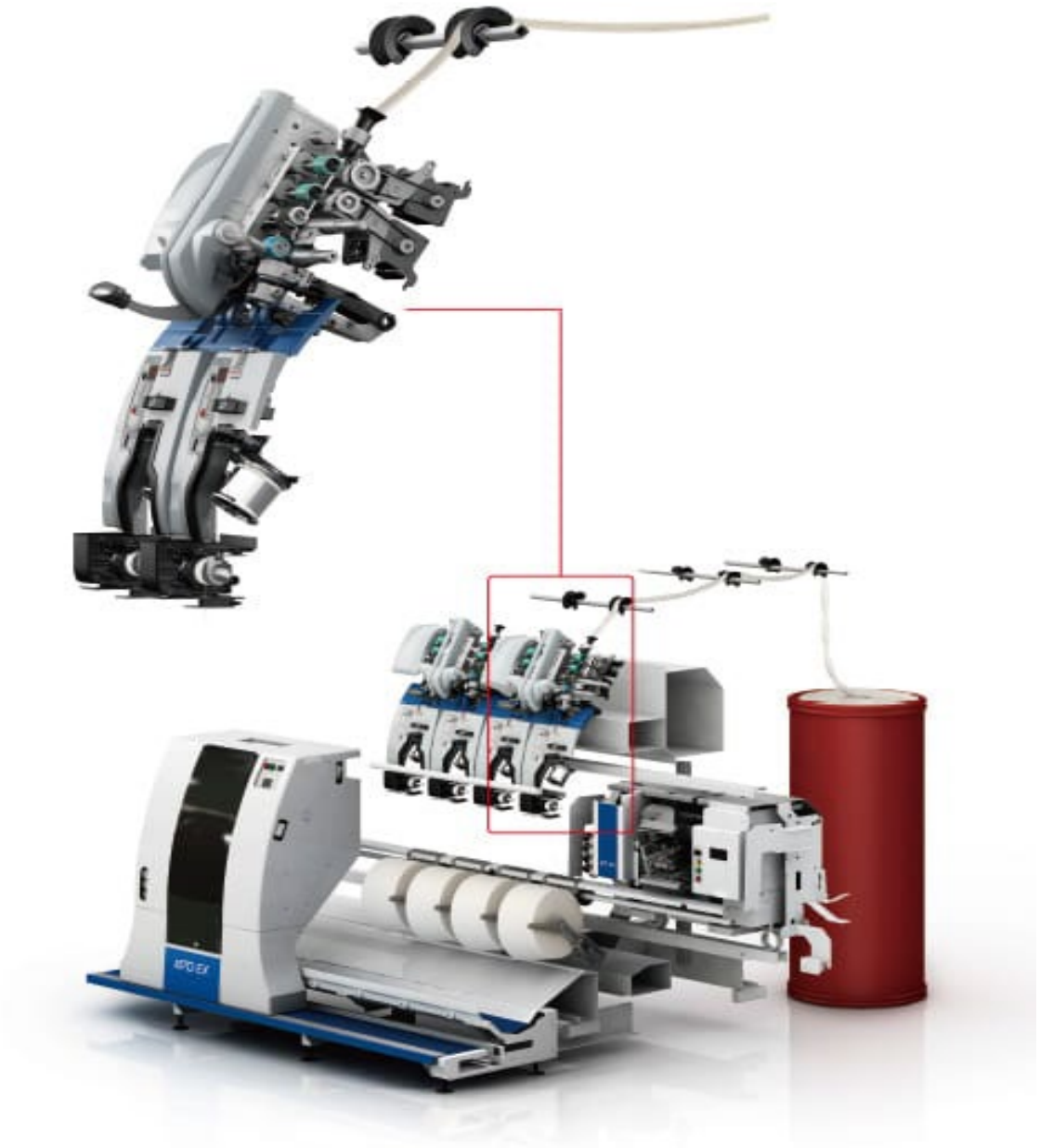
End Uses for Open End Yarns

- T-Shirts
- Underwear
- Heavy Sweatshirts
- Denim
- Home Furnishings



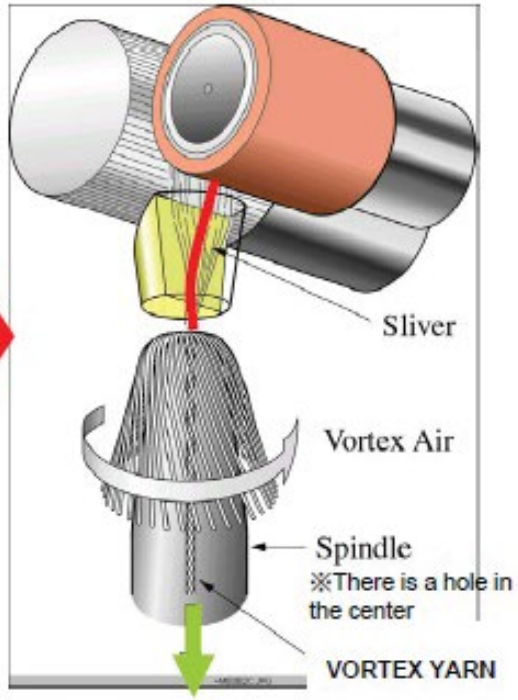
Vortex Spinning



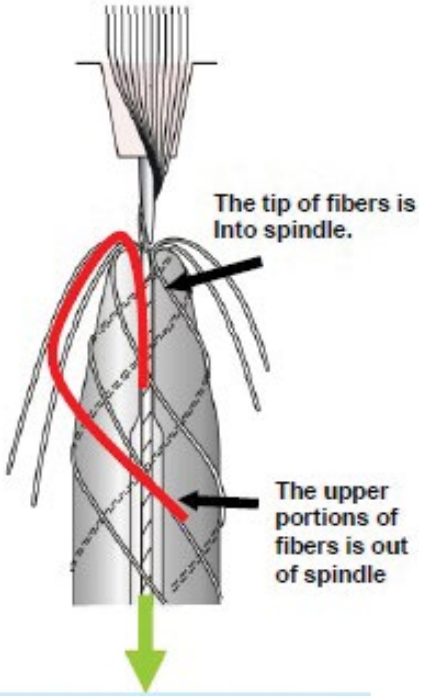


Vortex Spinning





While the roller holds the end of the fiber, the tip of the fiber goes to the hole of the spindle.

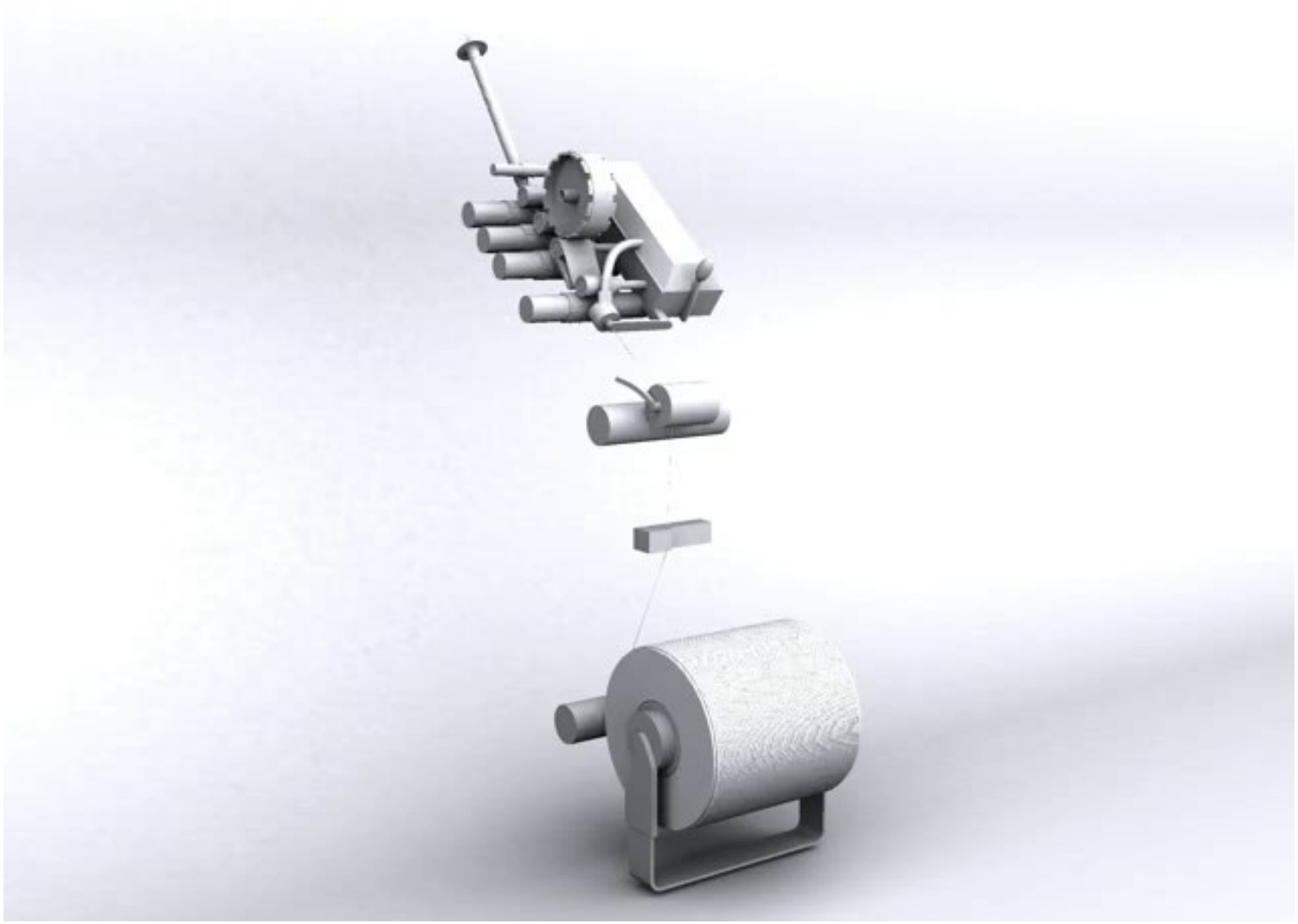


When the end of the fiber is release from the roller, fiber does not go through the spindle hole. It laps around the spindle by Vortex air

Air Jet Spinning Video



Vortex Spinning Animation

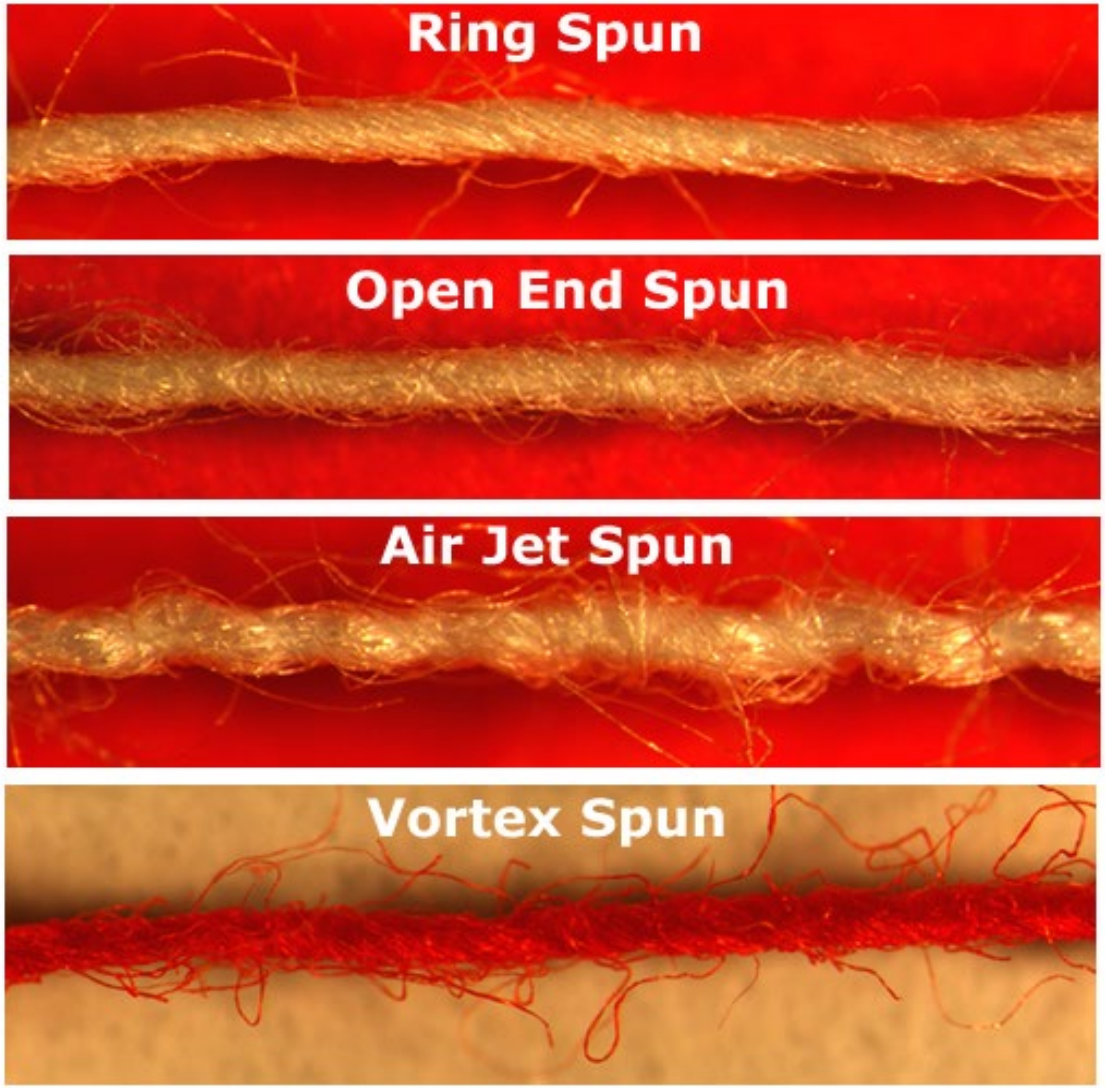


Vortex Spun Yarn Characteristics and End Uses



- All knits and fabrics in blends
- Medium-count sheeting
- Medium-count shirting
- Career apparel
- Industrial applications
- Military apparel
- Work wear
- Jersey knits

Spun Yarn Appearances



S and Z Twist





TWIST

- **Twist**
  - The spiral arrangement of the fibers/filaments around the axis of the yarn.
  - The twist binds the fibers/filaments together
  - It contributes to the strength of the yarn.
  - The amount of twist inserted also effects the softness/rigidity and the appearance of the yarn.

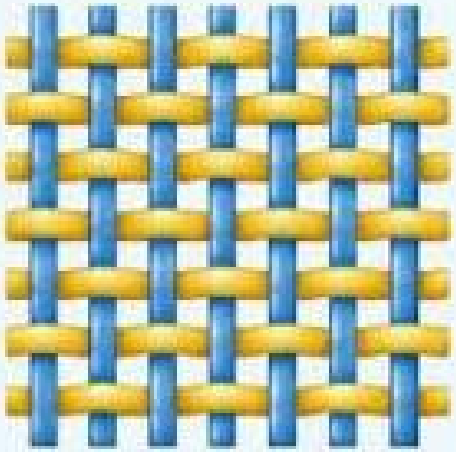
- **Twist Measurement**
  - The amount of twist is measured in **Turns Per Inch (TPI)**
    - in some cases internationally, in **Turns Per Meter (TPM)**
  - To convert turns per inch to turns per meter, multiply TPI by 39.36 inches per meter.
  - To convert TPM to TPI, divide TPM by 39.36.

TPI x 39.36 = TPM

TPM ÷ 39.36 = TPI

TYPES OF FABRIC STRUCTURE

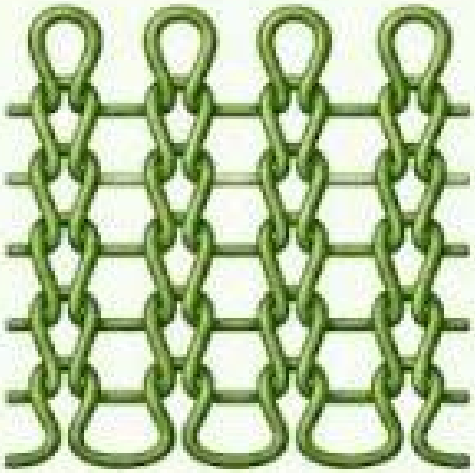
WOVEN



Made by interlacing two sets of yarns at right angles.

- Strong and durable
- Stable, holds shape well
- Low stretch

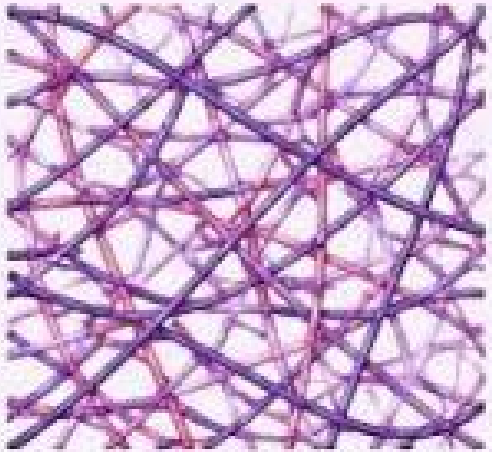
KNIT



Made by interlocking loops of yarn using a single yarn.

- Stretchy and flexible
- Soft and comfortable
- Good drape

NON-WOVEN

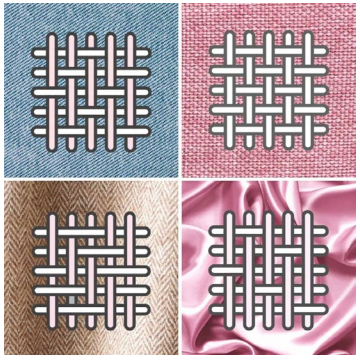


Made by bonding or felting fibers together chemically, thermally or mechanically.

- Lightweight
- High absorbency
- Cost-effective

Woven Fabrics

- Weaving: process of interlacing 2 or more yarns at right angles
- Warp: vertical yarns that run lengthwise through a fabric
- Filling: yarns run horizontally through a fabric
- EPI: number of ends per inch in the warp
- PPI: numbers of picks per inch in the filling
- Shed: opening created by the raising and lowering of ends to allow for insertion of a filling pick
- Major loom types: rapier, air-jet, water jet



Warping/Beaming



Warping/Beaming



Warper Creel



Yarn tensioning device



Electronic drop wires for the stop motion

Warping/Beaming

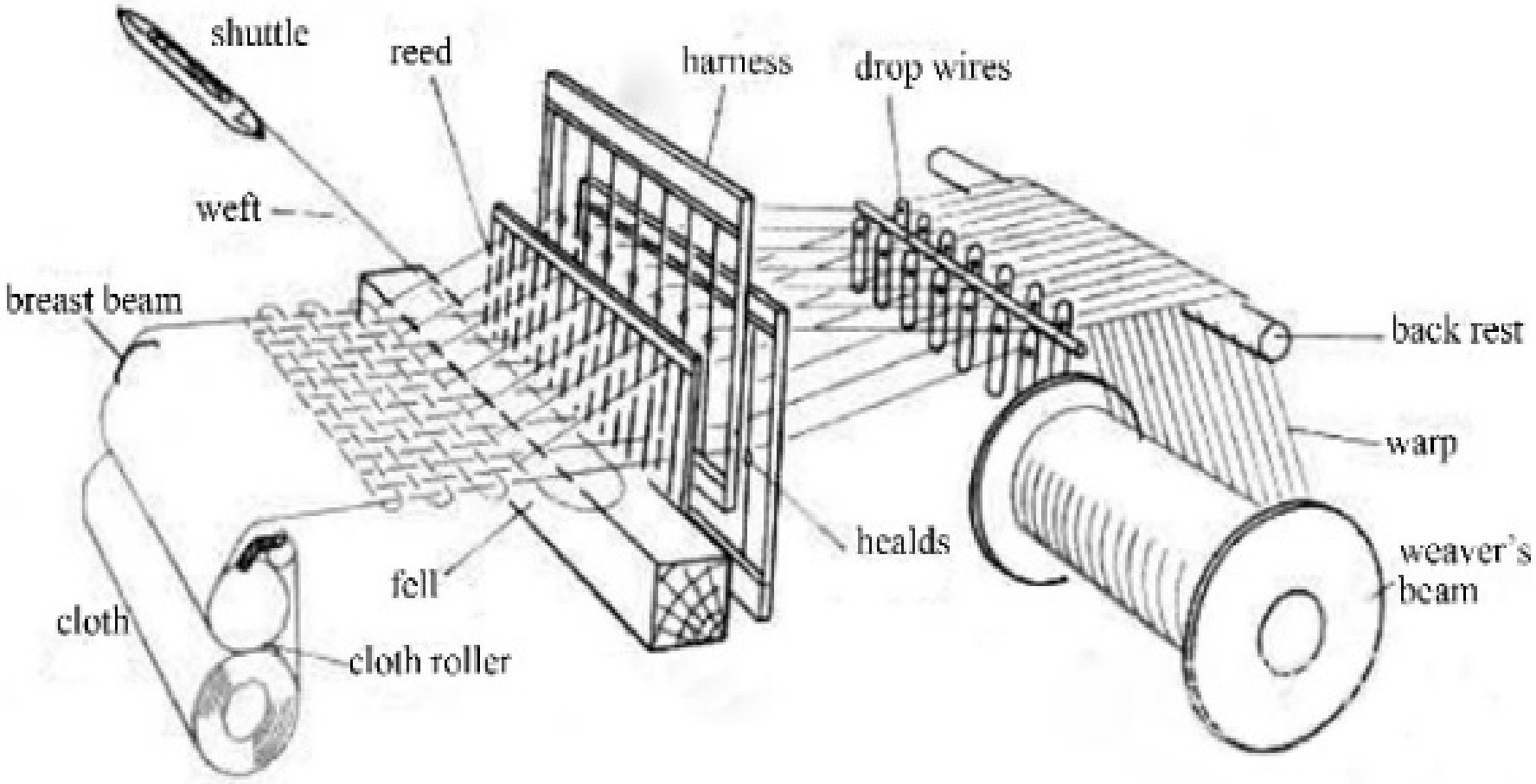


Warping/Beaming

Using the **Indirect warping system**, the warping and the preparation of a loom beam takes place on the same machine in two separate steps. This type of warper is advantageous when producing loom beams with striped patterns.



LOOM SCHEMATIC



Weaving Technology

These parts of the loom are involved in the **weaving cycle**:

1. **Shedding** by the up and down movement of the harnesses

2. **Picking** by the weft insertion mechanism

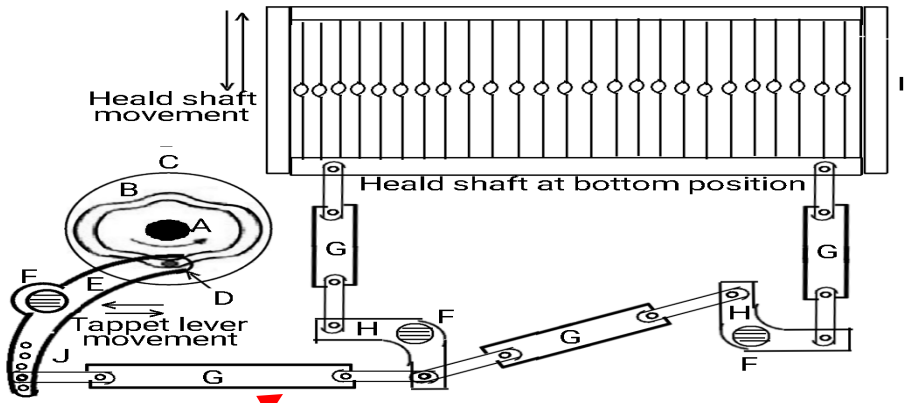
3. **Beating-up** by the reed pushing the weft yarn (pick) to the fell of the cloth

4. **Let-off** of the yarn off of the warp beam and **take-up** of the cloth onto the tube

Types of Shedding Motions

Conventional positive tappet shedding mechanism

A - Tappet shaft
B - Tappet track
C - Tappet
D - Bowl
E - Tappet lever
F - Fulcrum
G - Connecting rods
H - L- shape levers
I - Heald shaft
J - Heald shaft lift adjustment



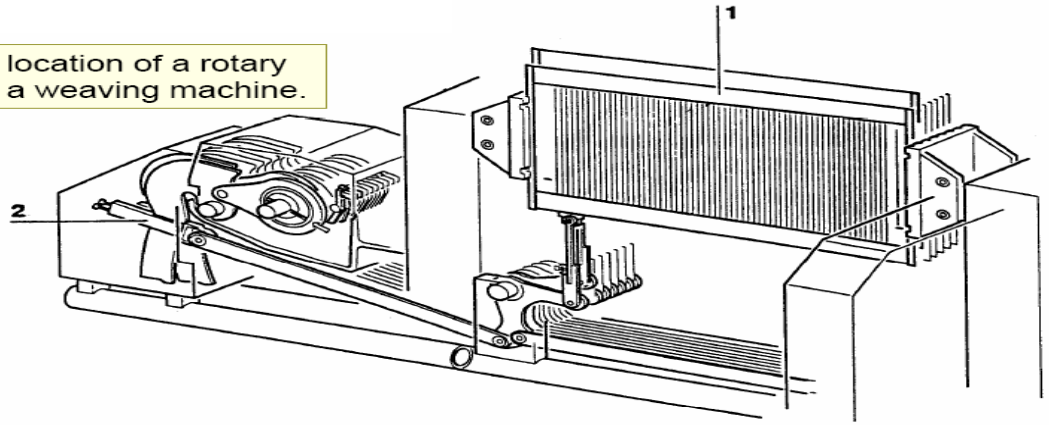
Cam or Tappet



Jacquard

Mounting location of a rotary dobby on a weaving machine.

Dobby



1 Shafts
2 Jack runners

Electronically controlled "Stäubli" rotary dobby

It is controlled by entering the fabric and machine-specific parameters at the terminal. The shed opening angle is modified symmetrically by moving jack runners **2**.

Types of Picking Motions

Picking

Picking is the insertion of the weft yarn (pick) once the shed has been formed. This occurs when one weft yarn is inserted from the left-hand side of the loom across the entire width of the loom.

Loom speed is determined by the number of picks inserted per minute. AKA: **PPM**

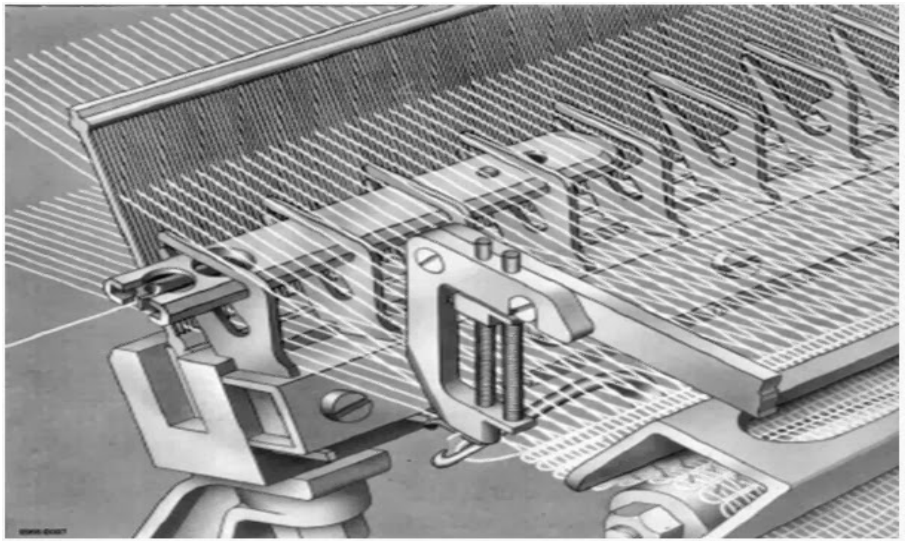
There are multiple types of weft insertion mechanisms. They are as follows:

- Shuttle
- Projectile/Rapier
- Water-jet
- Air-jet

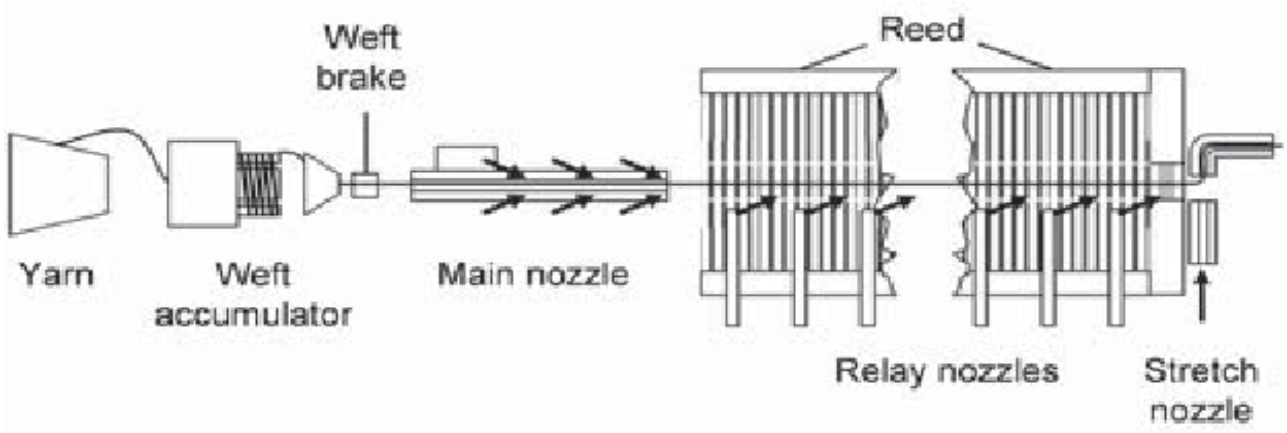
Types of Picking Motions



Shuttle Loom

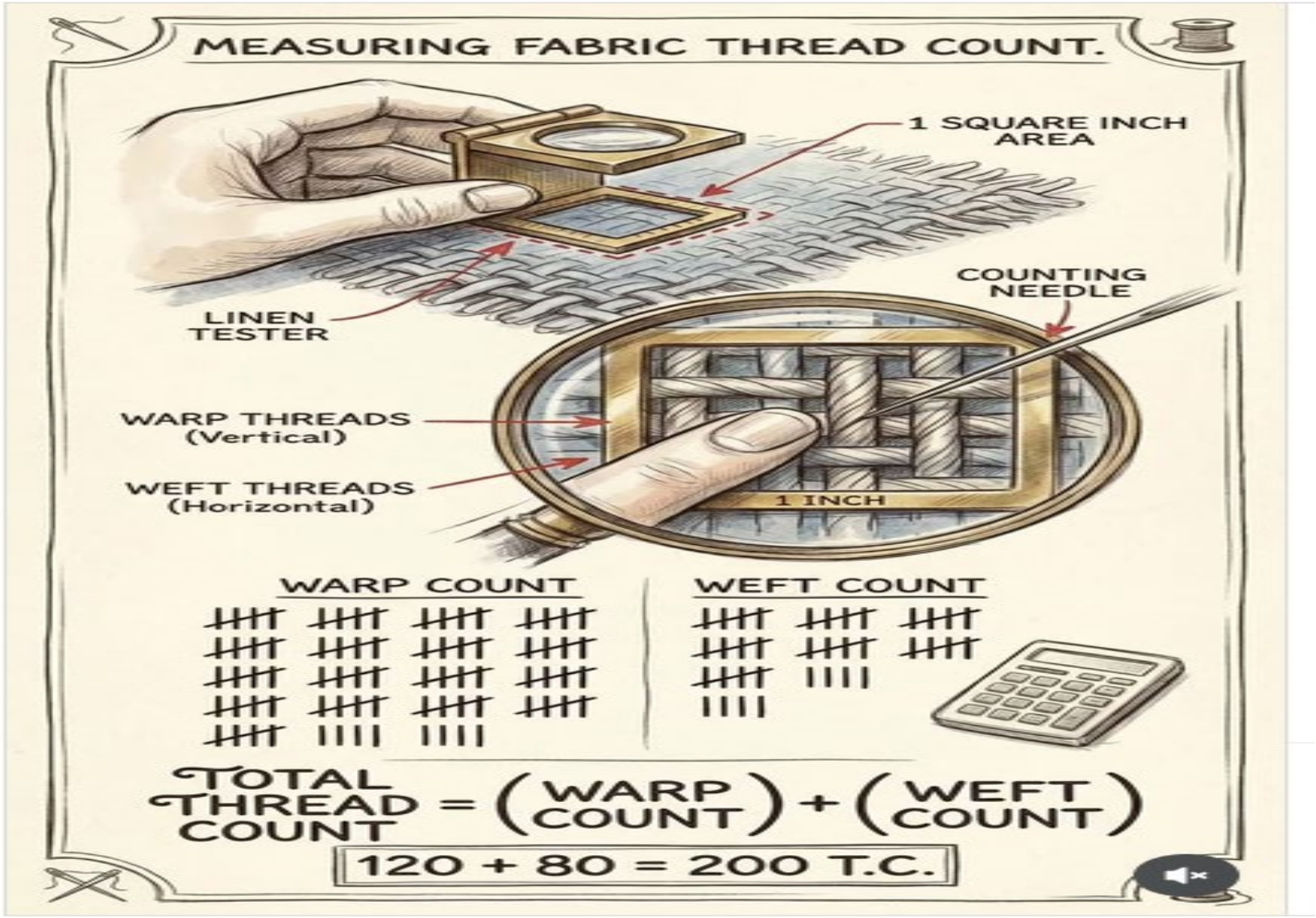


Projectile/Rapier Loom



Water Jet/Air Jet Loom

Warp Ends/Inch (epi) –Picks/Inch (ppi)



Popular Woven Fabric Designs

- Plain
- Basket
- Twill
- Sateen



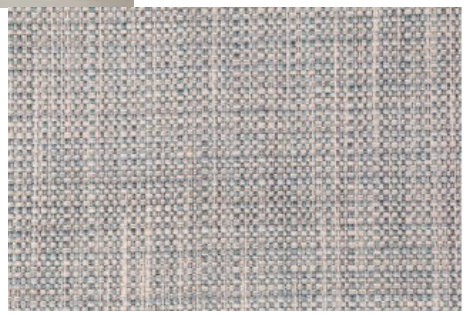
Chiffon



Denim



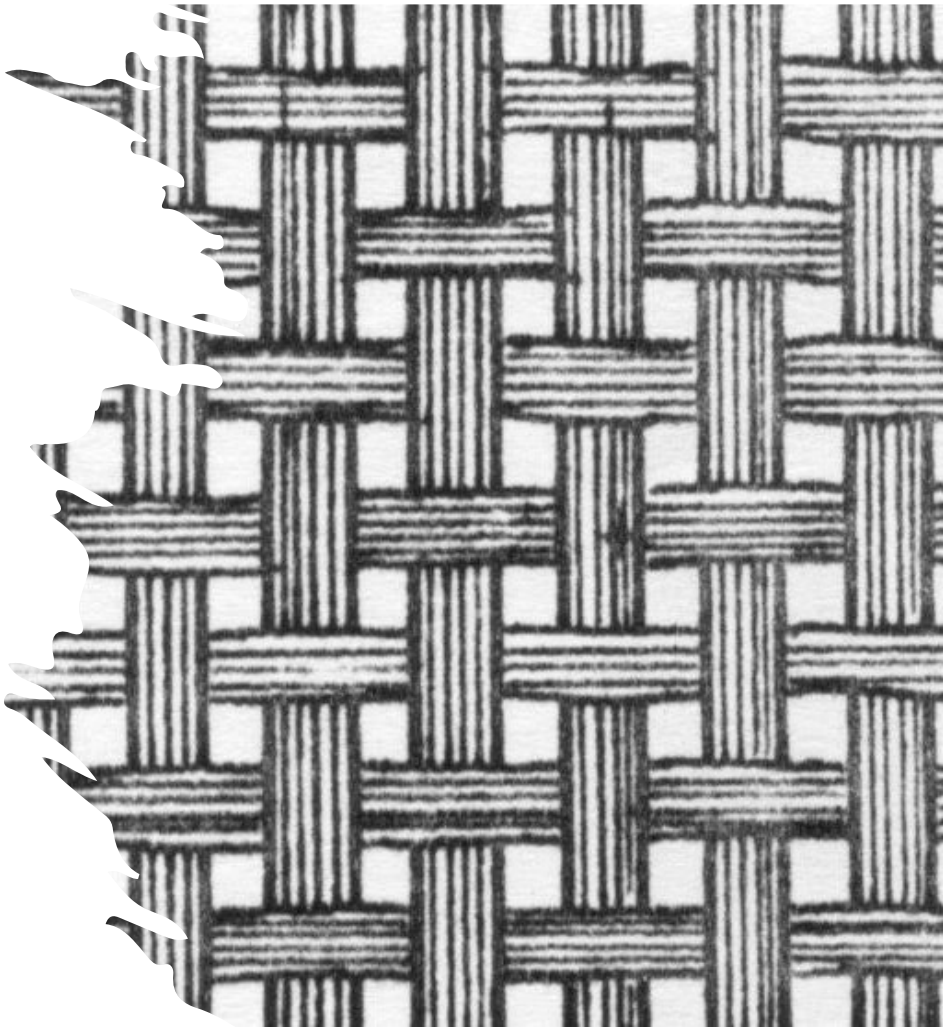
Bedding

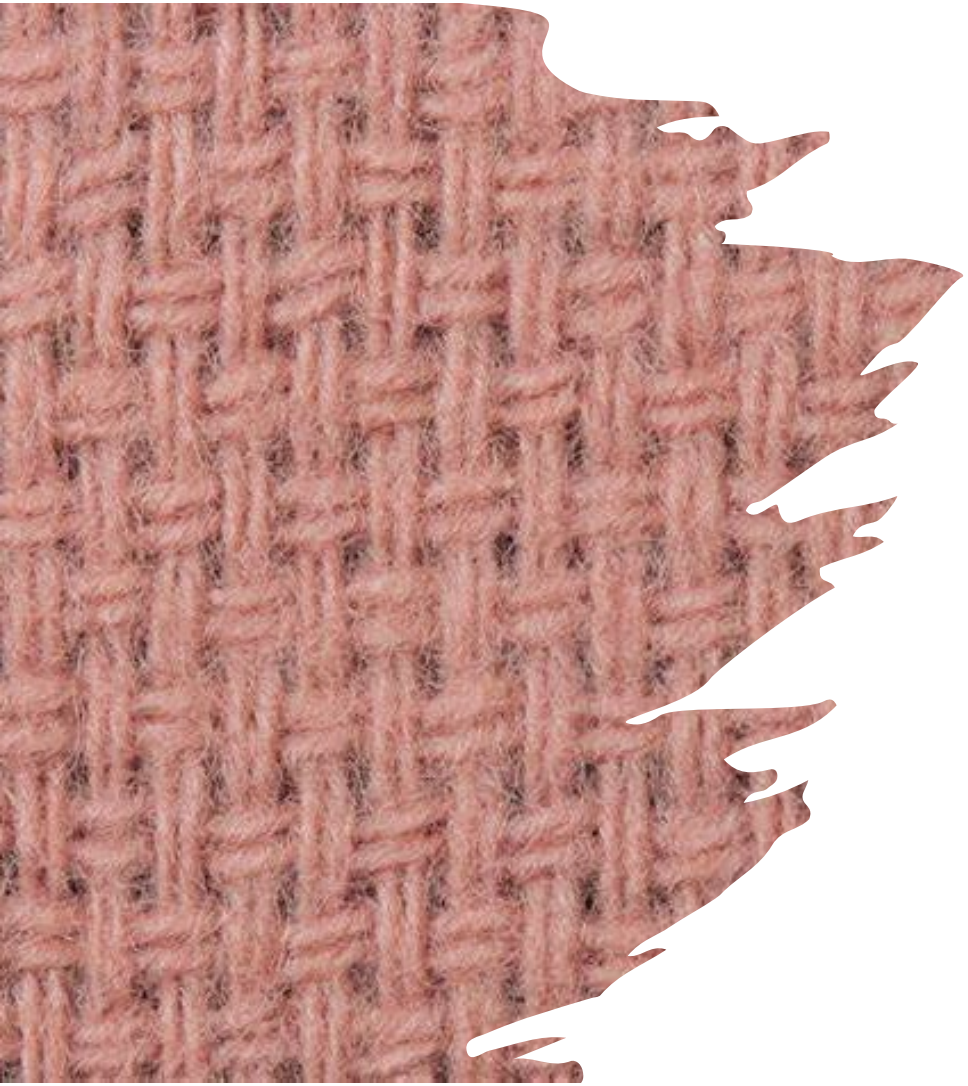


Upholstery

Patterns of Weaving

- ***Plain weave is the simplest and most basic type of pattern. The fabric is assembled by the weft yarn running through the warp yarn in an "over and under" sequence. Plain weave fabrics are normally very strong, versatile and durable, due to the high density of the fabric. This fabric is not very pliable and does not drape well. End uses include electronics and coated products.***





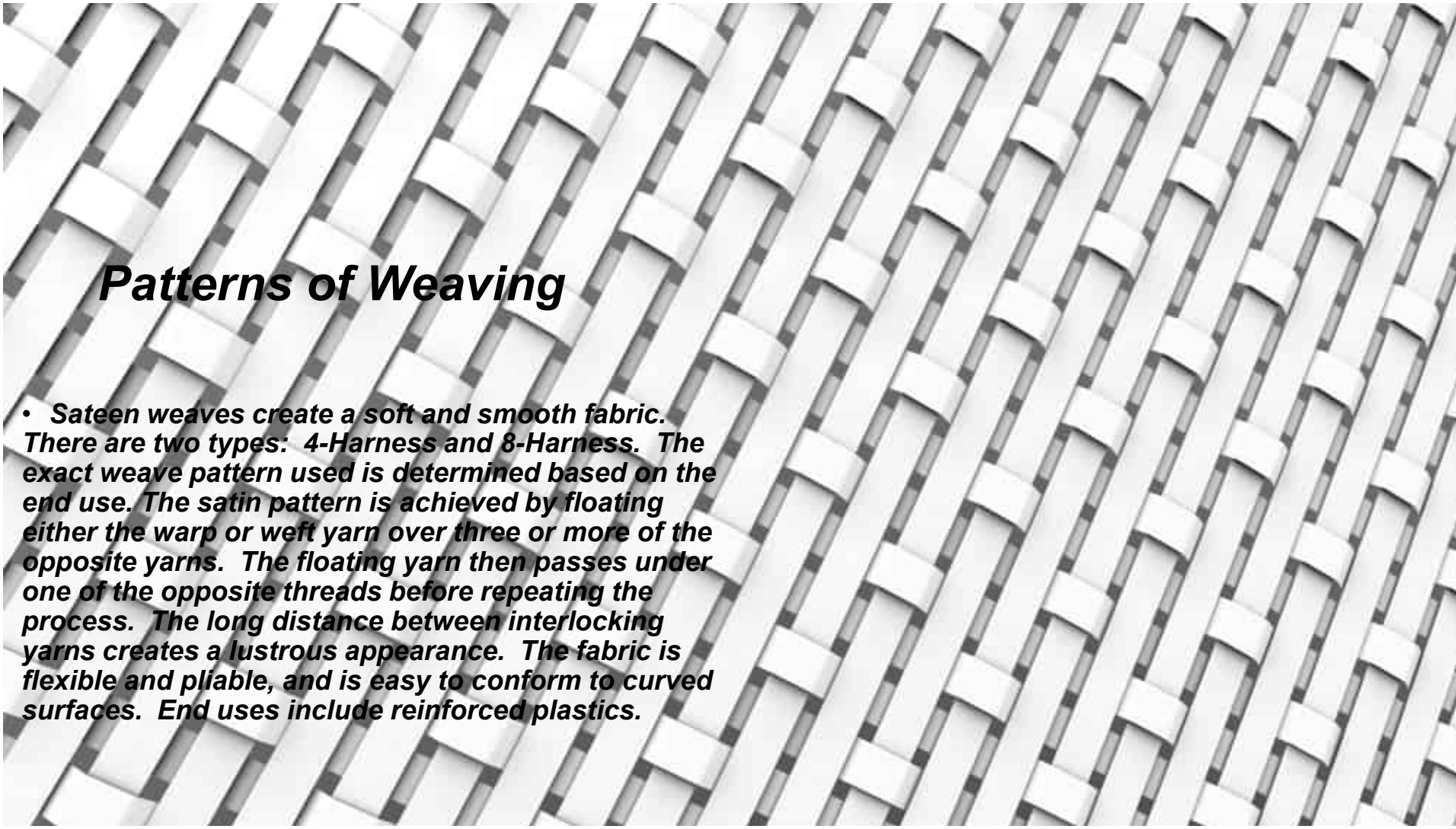
Patterns of Weaving

- ***The Basket weave pattern is similar to the plain weave, except it uses two or more warp and weft yarns combined and woven as one. This results in a more textured fabric with an emphasized checkerboard appearance. The Basket weave is not quite as stable as the plain weave. However, it is flatter, stronger and more pliable.***

Patterns of Weaving

- ***The Twill pattern is the most commonly used weave patterns in textile production. The Twill creates a pattern of diagonal lines (ribs) by passing the weft yarn under and over several warp yarns in an alternating pattern. This type of pattern is ideal for applications requiring strong, high-density fabrics. This type of fabric is more pliable and therefore, has better drapability. However, it is more susceptible to fraying. End uses for this type of patter are automotive fabrics and denims.***



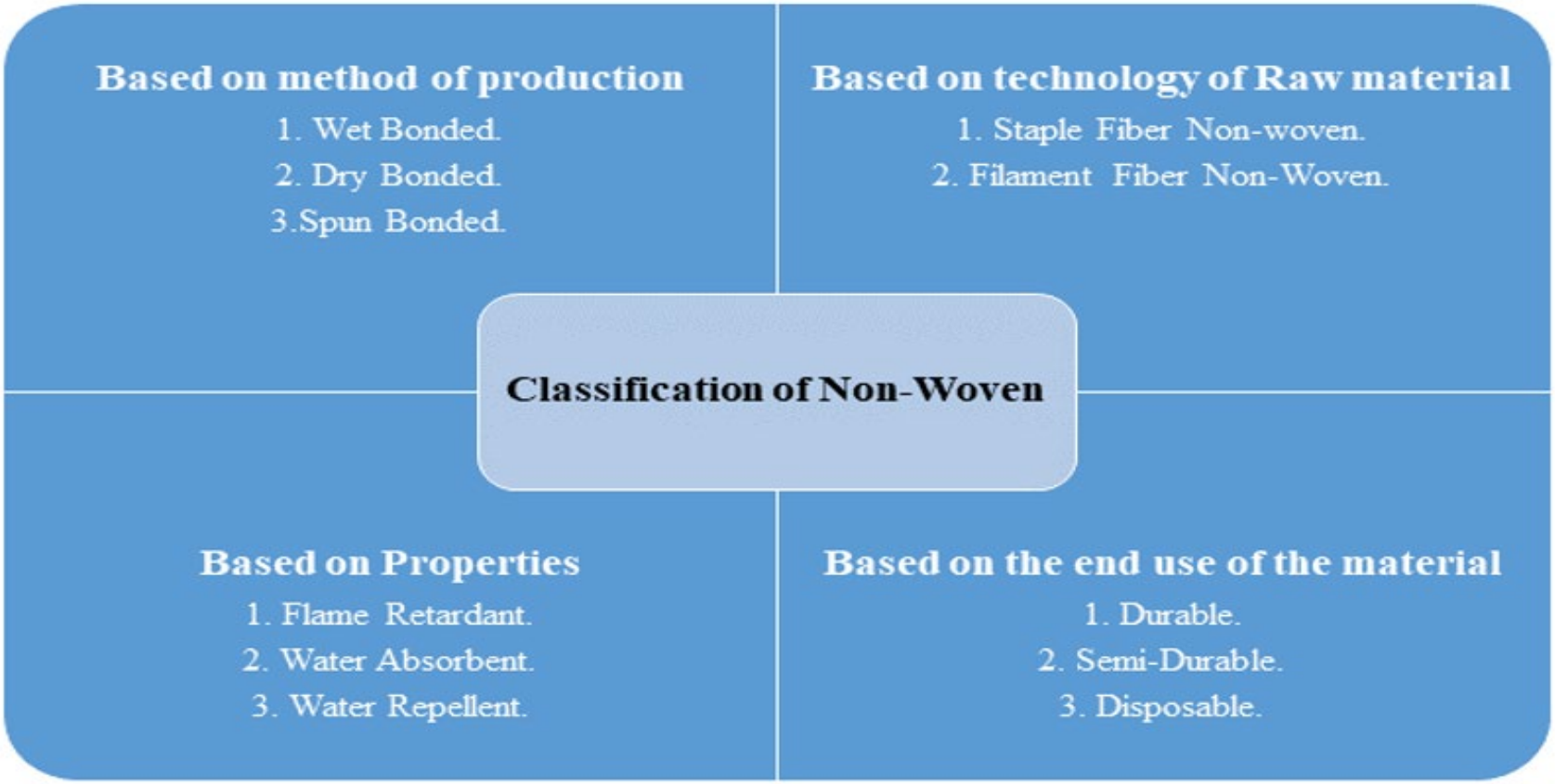


Patterns of Weaving

- ***Sateen weaves create a soft and smooth fabric. There are two types: 4-Harness and 8-Harness. The exact weave pattern used is determined based on the end use. The satin pattern is achieved by floating either the warp or weft yarn over three or more of the opposite yarns. The floating yarn then passes under one of the opposite threads before repeating the process. The long distance between interlocking yarns creates a lustrous appearance. The fabric is flexible and pliable, and is easy to conform to curved surfaces. End uses include reinforced plastics.***

Nonwoven Fabrics

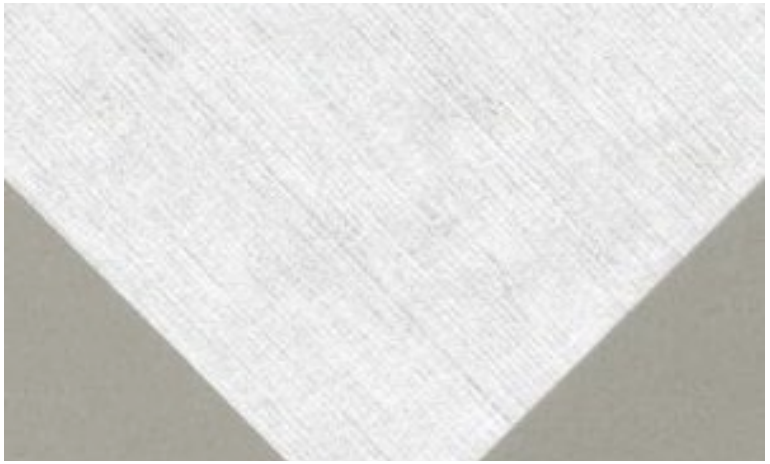
- Nonwoven fabrics are made from various web formations that are bonded by mechanical, chemical, thermal or solvent methods.



Examples of Nonwoven Fabrics



Baby Diapers



Wipes

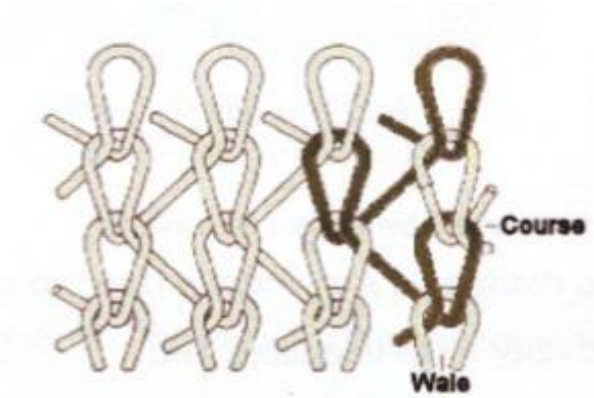


Medical Supplies

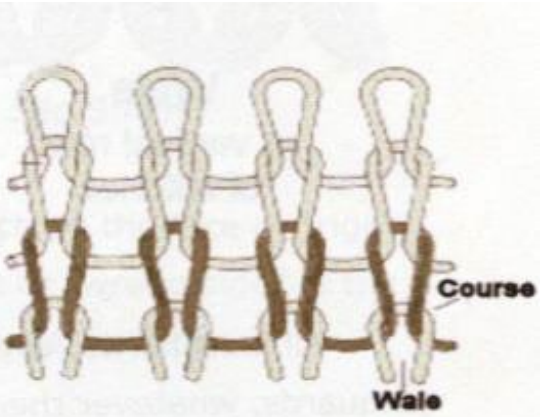
Knit Fabrics

- Knitting: fabric formation created by the interlacing of stitches
- Wales: row of interlocking loops that run lengthwise in the fabric
- Courses: row of interlocking loops that run crosswise in the fabric
- Main knitting types: weft knitting, warp knitting
- Gauge or cut: # of needles per inch on the machine

Knit Fabrics



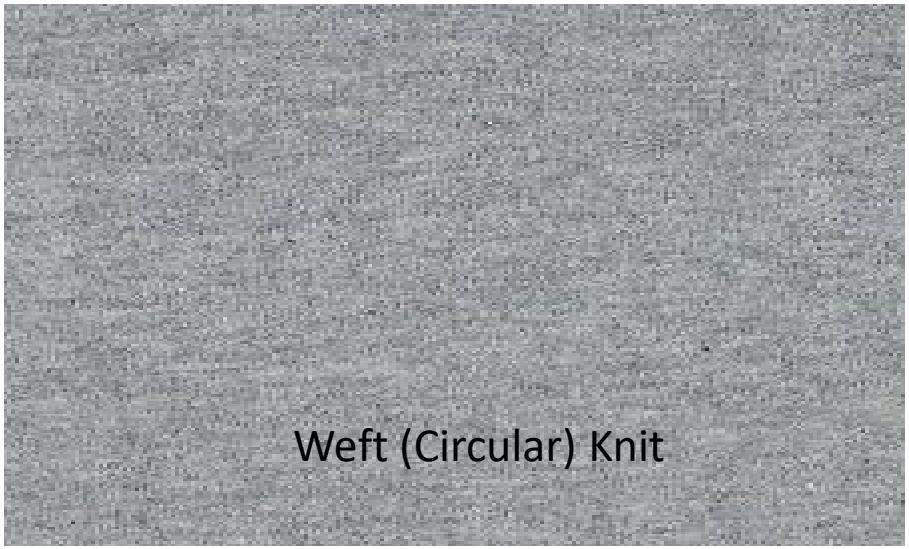
A WARP KNIT



A WEFT KNIT



Warp Knit



Weft (Circular) Knit

Warp Knit Fabrics

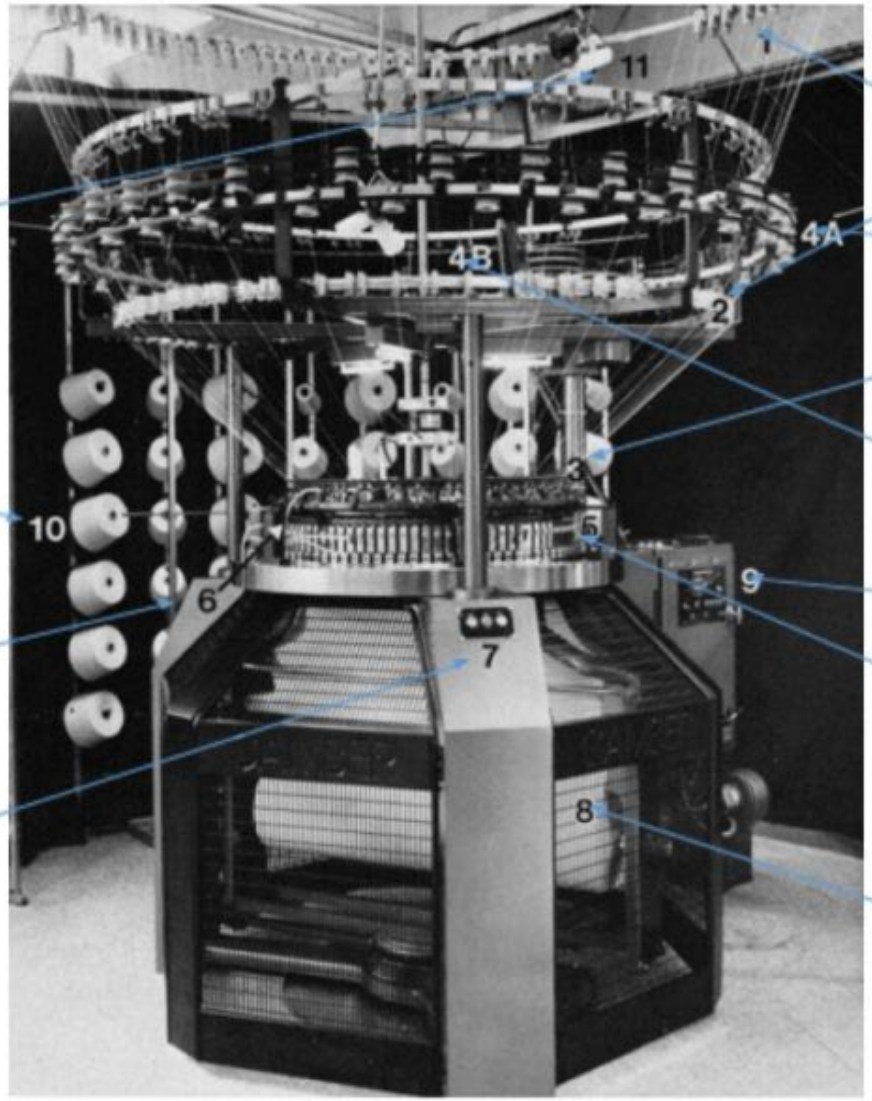


Warper



Warp Knitting M/C

Weft Knit Fabrics - Circular



Lint blower

Stop motion

Positive feed

Spring-loaded detector points

Side creel

Drive arrangement

Revolution counter

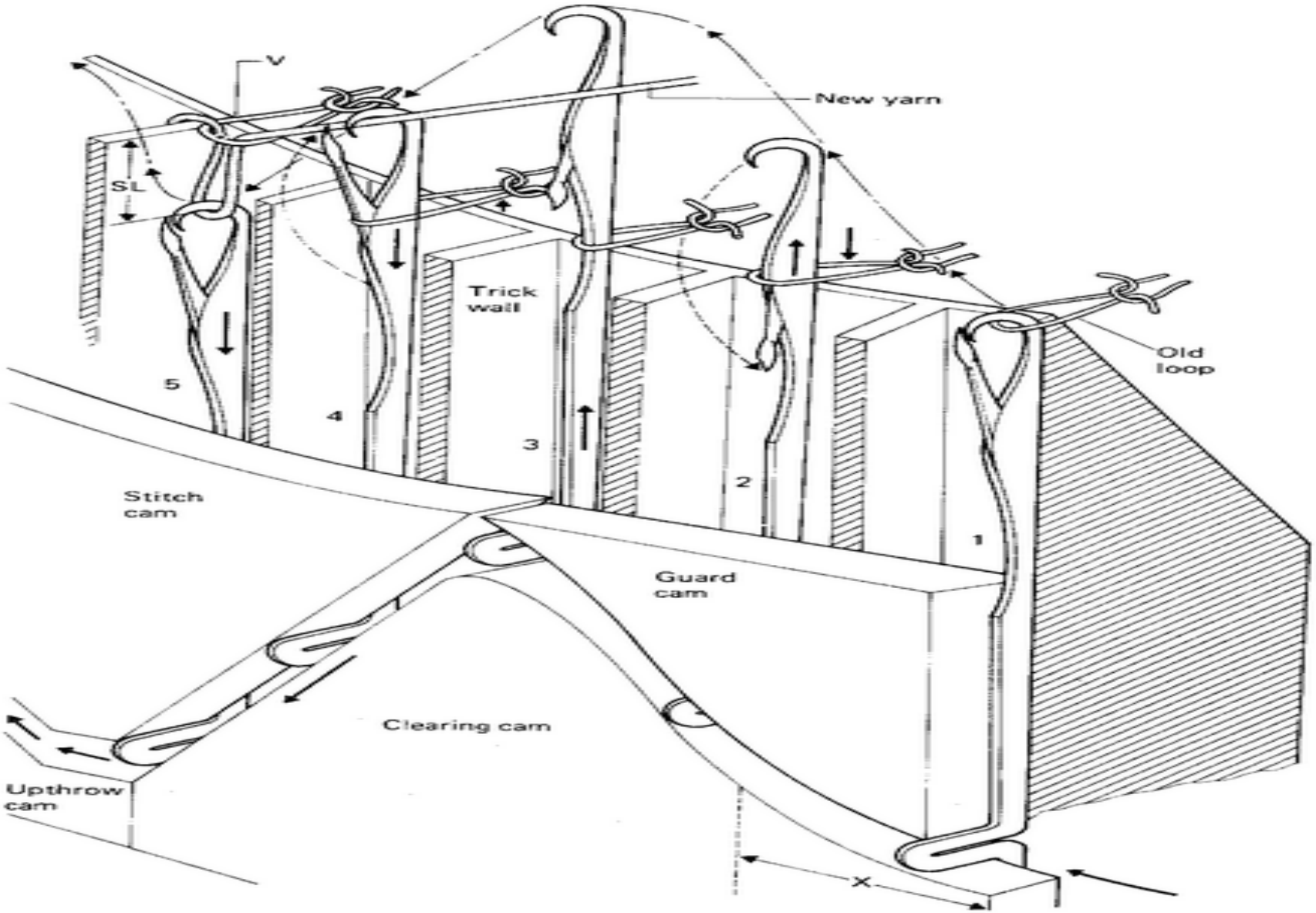
Automatic lubrication system

Cylinder needle cam system

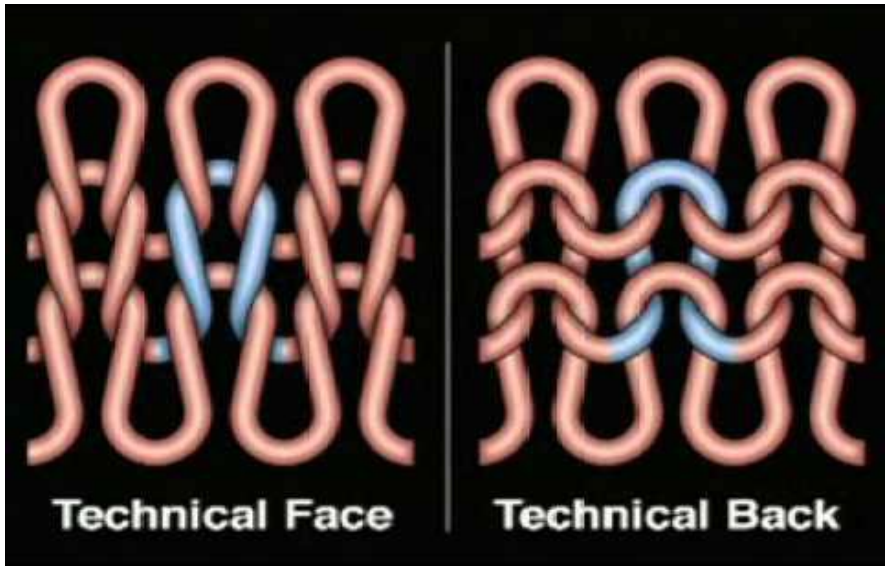
Start, stop and inching buttons

Fabric winding down mechanism

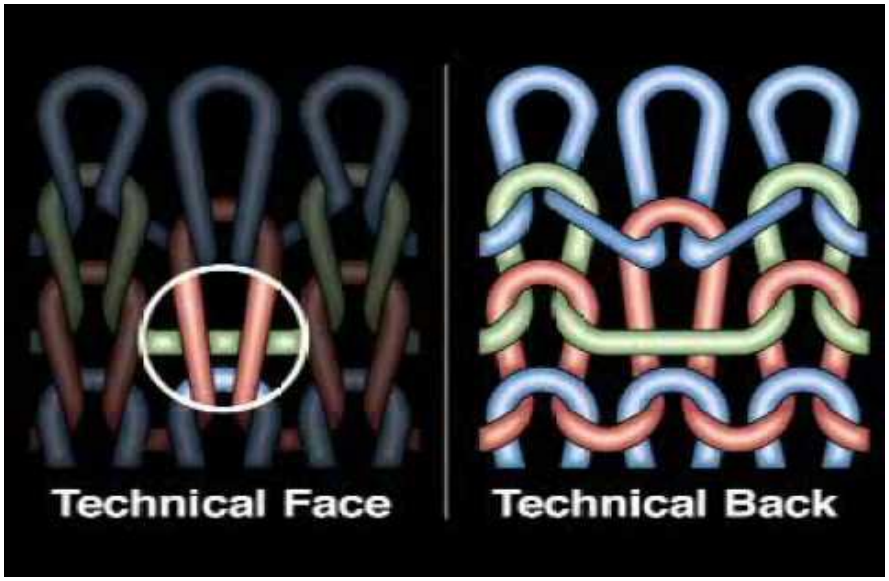
Circular Knitting – Latch Needle/Needle Cam



Types of Circular Knit Stitches



Jersey Stitch



Tuck Stitch

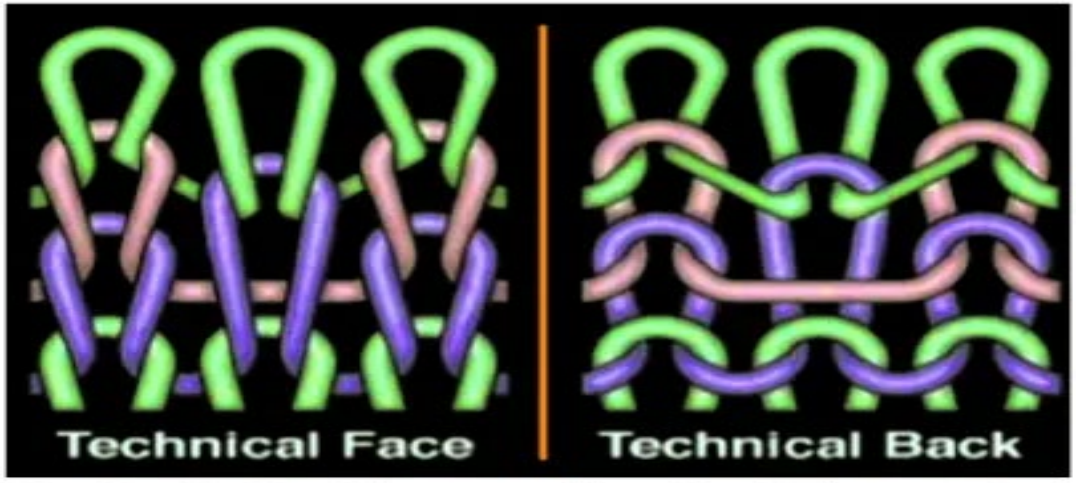


Fig: Technical face and back of Float Stitch

Dyeing and Finishing Preparation Processes

Another important factor is the quality of the water used for cleaning and dyeing. Poor water quality can effect:

- Dye Preparation (cleaning)
- Dyeing
- Finishing

Water quality can be effected by:

- Water hardness
- Water pH
- Suspended solids
- Color of the water
- Dissolved minerals such as iron, copper and zine
- Chlorine content

Dyeing and Finishing Preparation Processes

There are three basic steps in the Dyeing and Finishing preparation process:

- **Cleaning/Scouring** – The removal of oils, natural and applied waxes, spin finishes, sizing and other soiled spots from both knit and woven fabrics.
  - *Important in preventing off-quality dyeing and finishing.
  - *Process is performed at 120-180 degrees Fahrenheit.
  - *Removal of wax layer in cotton based products allows water-based dyeing and finishing chemicals to penetrate the fiber.
  - *Removal of size (desizing) for woven goods only.

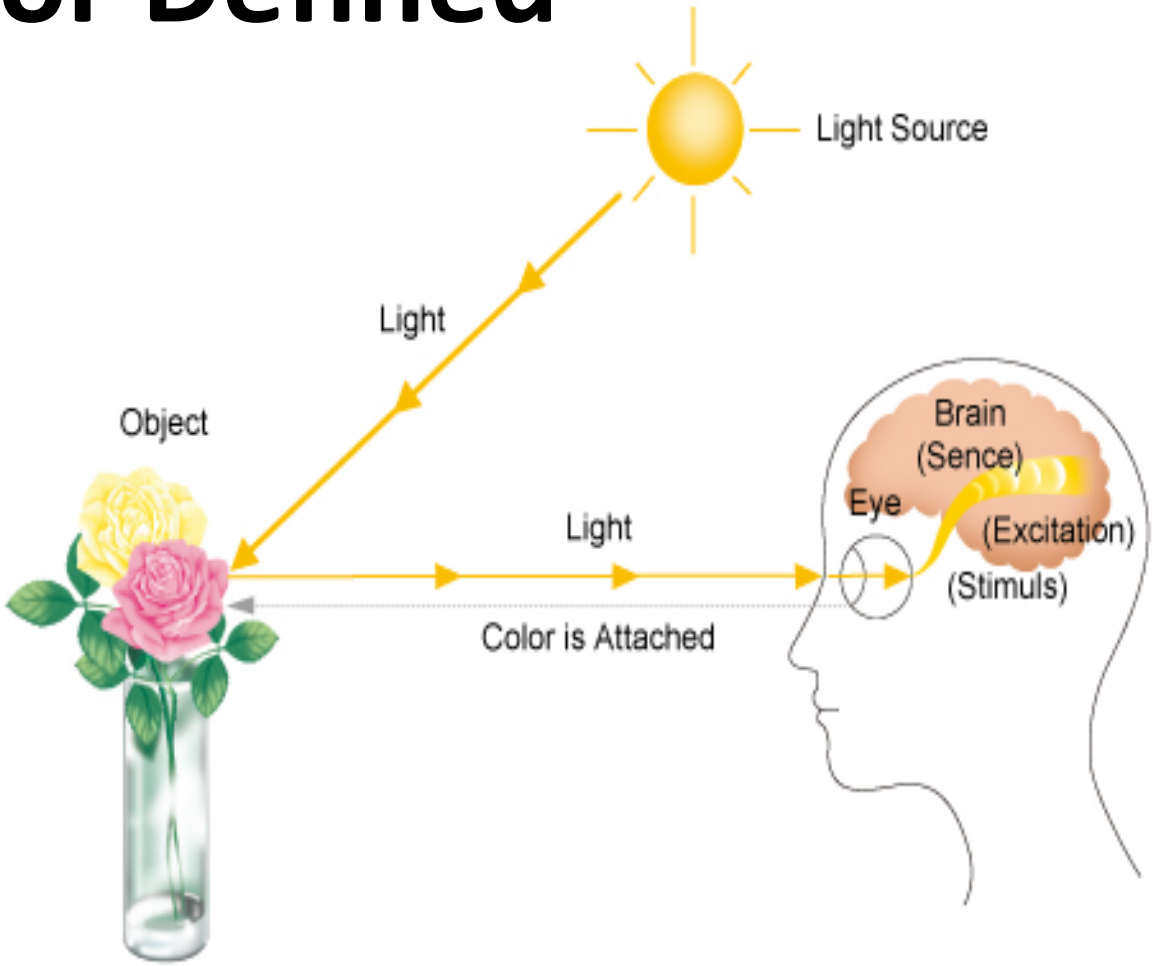
- **Bleaching** – For yarns and fabrics requiring a very white end product. Usually, after bleaching the yarn/fabric is treated with an optical brightener to obtain a very good bright white.
  - *Important for cotton, flax, ramie, etc. that are not white in a natural state.
  - *Important for yarns/fabrics to be dyed in whites and light pastels.
  - *Chlorine or peroxide type of bleached used depending on the fiber and dyes to be used.
  - *Bleach bath temperatures range from 120 F to 212F, dependent on fiber type, bleach used and its' concentration and the degree of whiteness required.
  - *Bleached yarn/fabric must be neutralized prior to dyeing and finishing.

Dyeing – Dye Class and Fiber Types

Fibre	Dye class having affinity	Types of dye-fibre bonds
Cellulosic: cotton, jute, rayon, etc.	Direct, vat, solublised vat and sulphur dye	Van der Waals' forces and hydrogen bonding
	Reactive dye	Covalent bonds
Protein/polyamide: wool, silk, nylons	Direct, acid, metal complex and basic dye	Ionic bond or electrostatic bonds
	Reactive dye	Covalent bonds
Polyester	Disperse dye	Van der Waals' forces and hydrogen bonding
Acrylic	Cationic	Ionic bond or electrostatic bonds
	Disperse dye	Van der Waals' forces and hydrogen bonding

Color Defined

- A light source
- A surface for the light to reflect from
- An observer of reflected wavelengths



Color Defining Variables

Types of light sources:

The textile industry utilizes three major types of light sources which are available in a Macbeth Light Box:

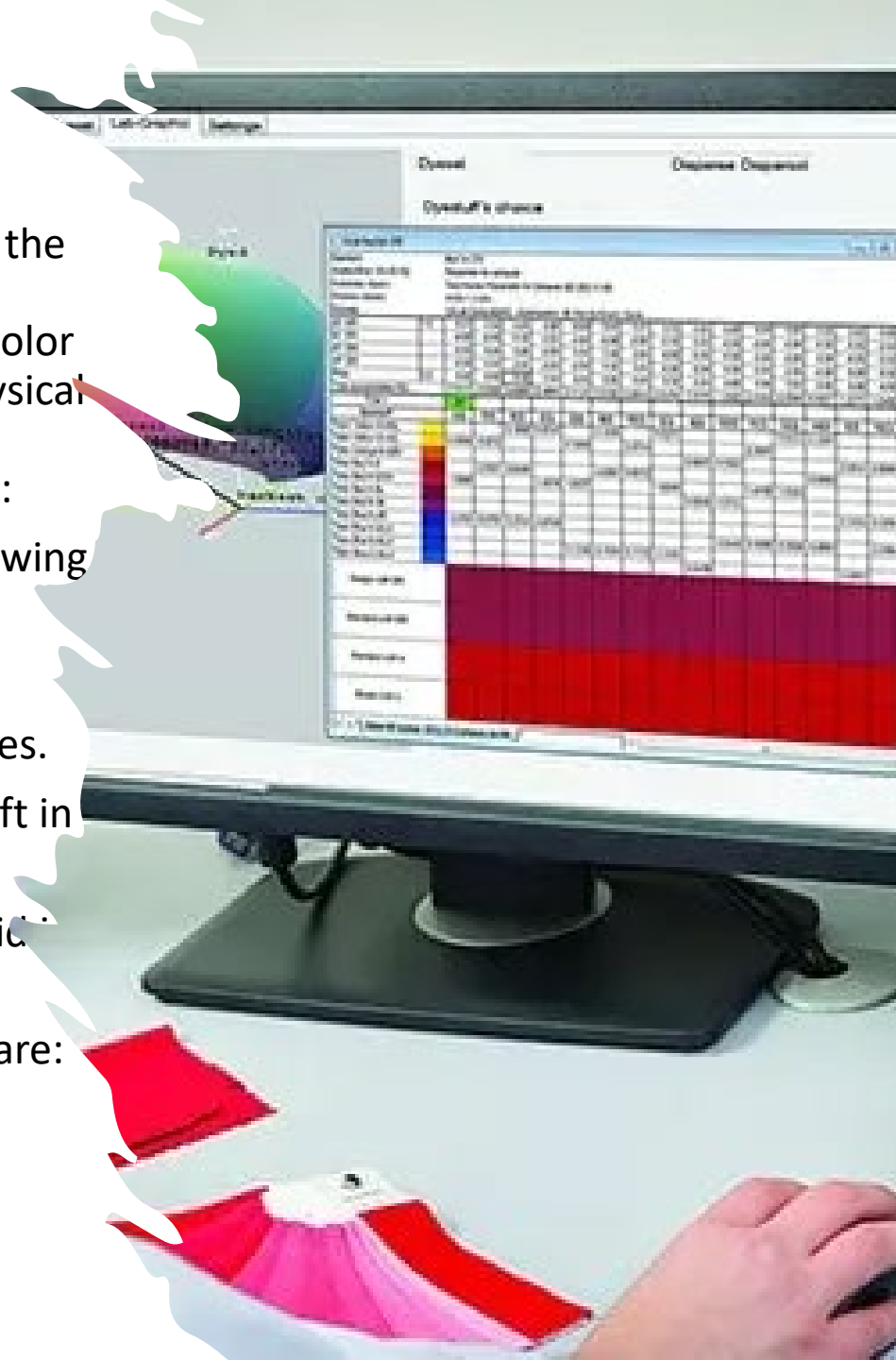
D65 – Daylight at noon (a bluish light)

CWF – Cool white fluorescent light (yellowish light)

Illuminant A – Horizon or tungsten light (orange light)

Spectrophotometers

- Color computers are not a replacement for the human eye in matching and controlling color. However, they are a tremendous aid. These color systems have been devised to give color a physical space of mathematical numbers that can by studied and compared and operate as follows:
- Develop color on a computer screen for viewing
- Read the reflectance curve of an object to develop a dye formula to match its' color.
- Can confirm/disagree with color the eye sees.
- Can be used as a QC aid to control color drift in production lots.
- Can show the effects of metamerism and aid in selecting dyes to control the effect.
- Systems that are used in production today are:
- Datacolor X - Rite
- Hunter Labs Minolta

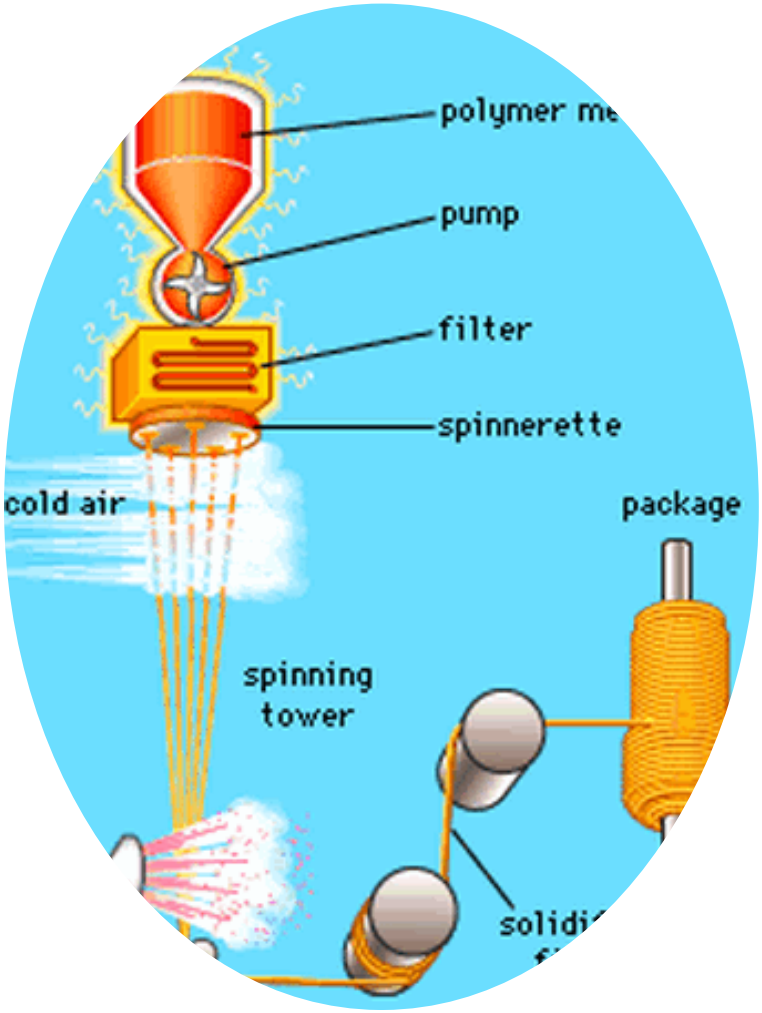


Types of Dyeing

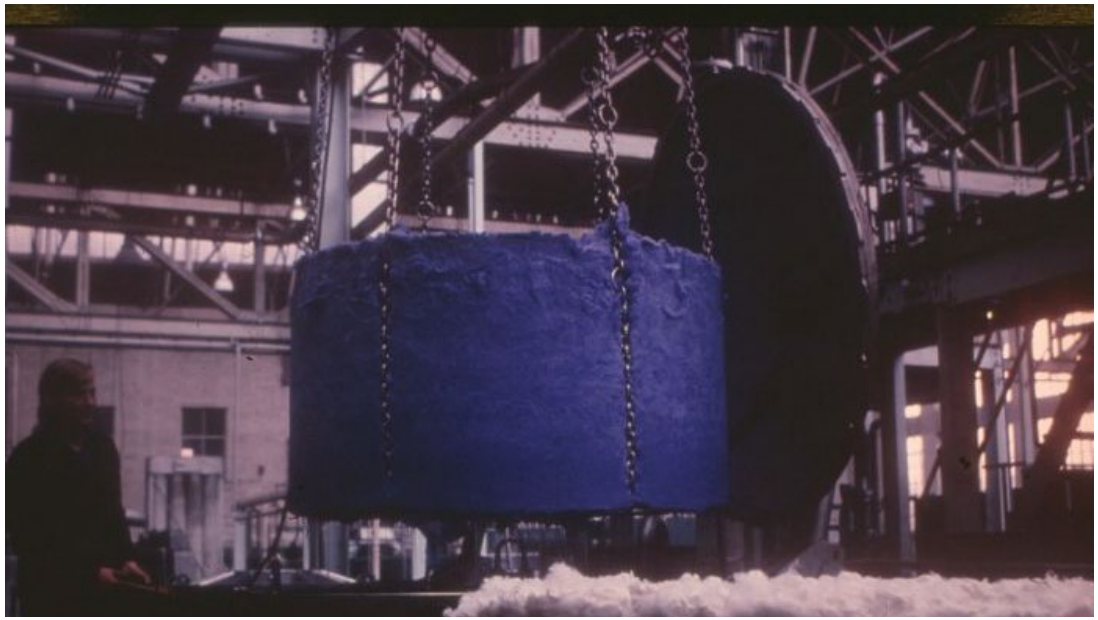
- ***Solution (loose fiber)***
- ***Stock (loose fiber)***
- ***Yarn***
- ***Piece (fabric)***
- ***Garment***



Types of Dyeing



Solution Dyeing



Stock Dyeing

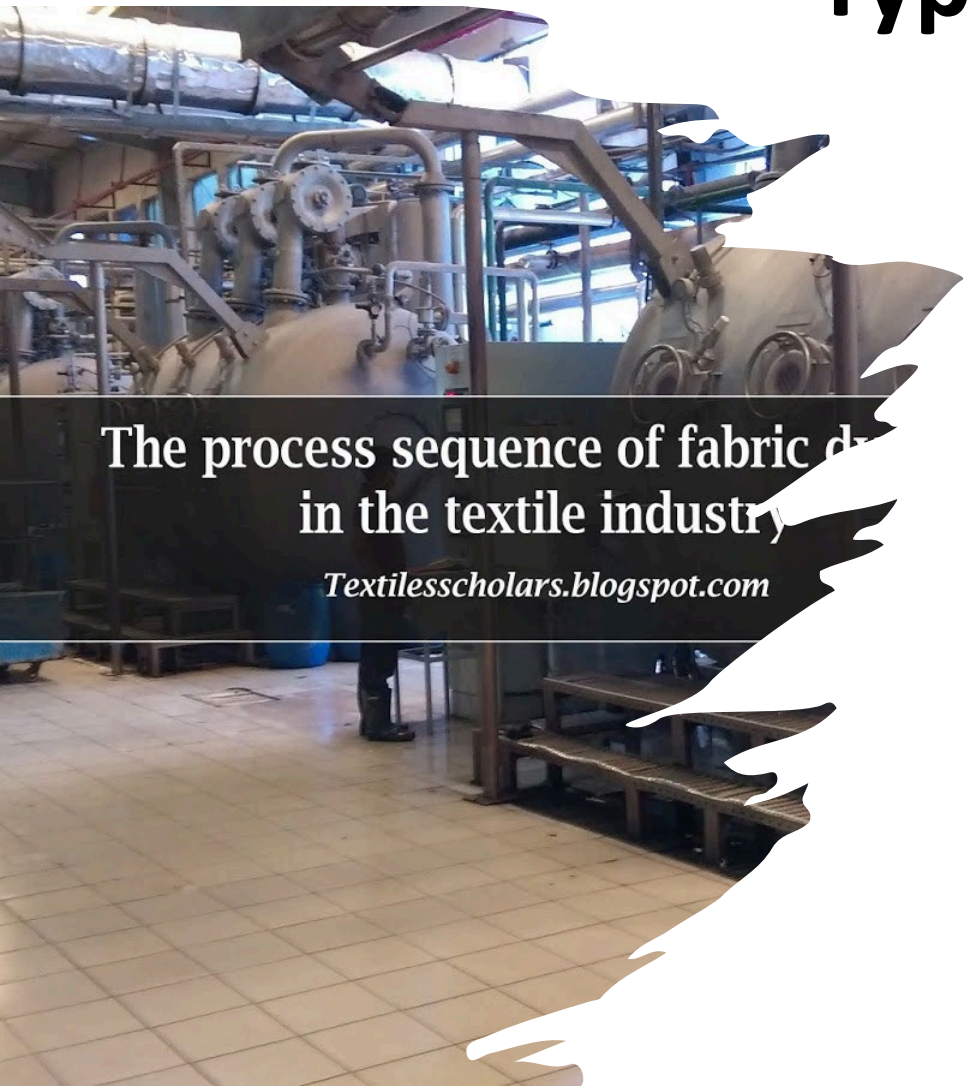
Types of Dyeing





Package/Yarn Dyeing

Types of Piece Dyeing



- The dyeing of cloth after it has been woven or knitted is known as “Piece Dyeing”.
- It is the most common method of dyeing used. The various methods used for this type of dyeing include:
  - ❖ Jet Dyeing
  - ❖ Jig Dyeing
  - ❖ Pad Dyeing
  - ❖ Beam Dyeing
  - ❖ Garment Dyeing

Jet Dyeing

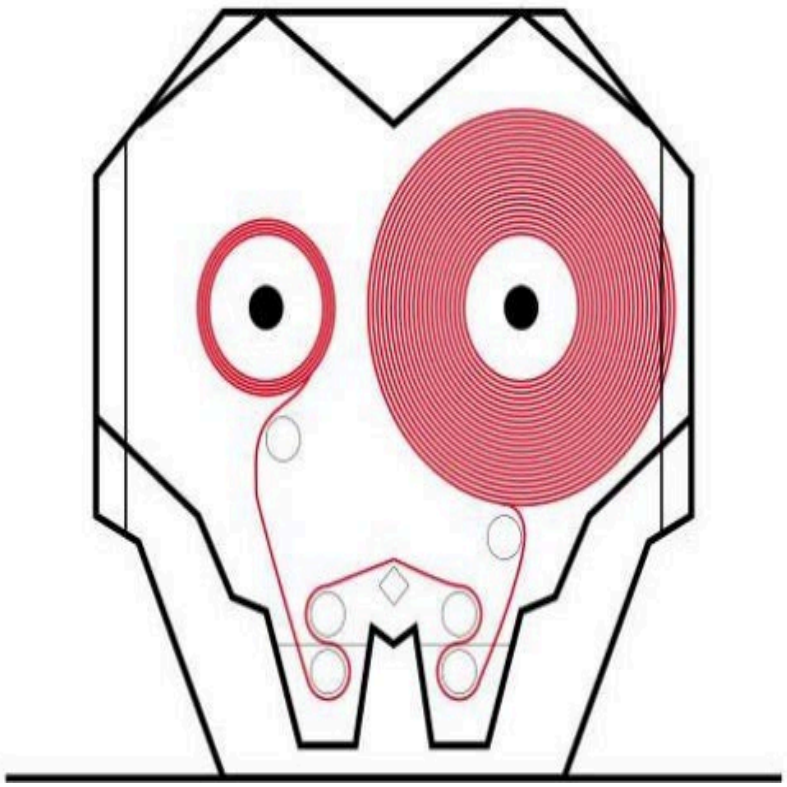
- Jet dyeing is the process used for batch dyeing operations.
- The dyeing is accomplished in a closed tubular system, basically composed of an impeller pump and a shallow dye bath.
- The fabric is to be dyed in a loosely collapsed rope form, with the two ends being tied together to form a loop.
- The impeller pump supplies a jet of dye solution, propelled by water and or air, which transport the fabric within the dyeing system, surrounded by the dye liquor.
- Turbulence is created by the jet aids in dye penetration and prevents the fabric from touching the walls of the tube, minimizing any mechanical impact on the fabric.



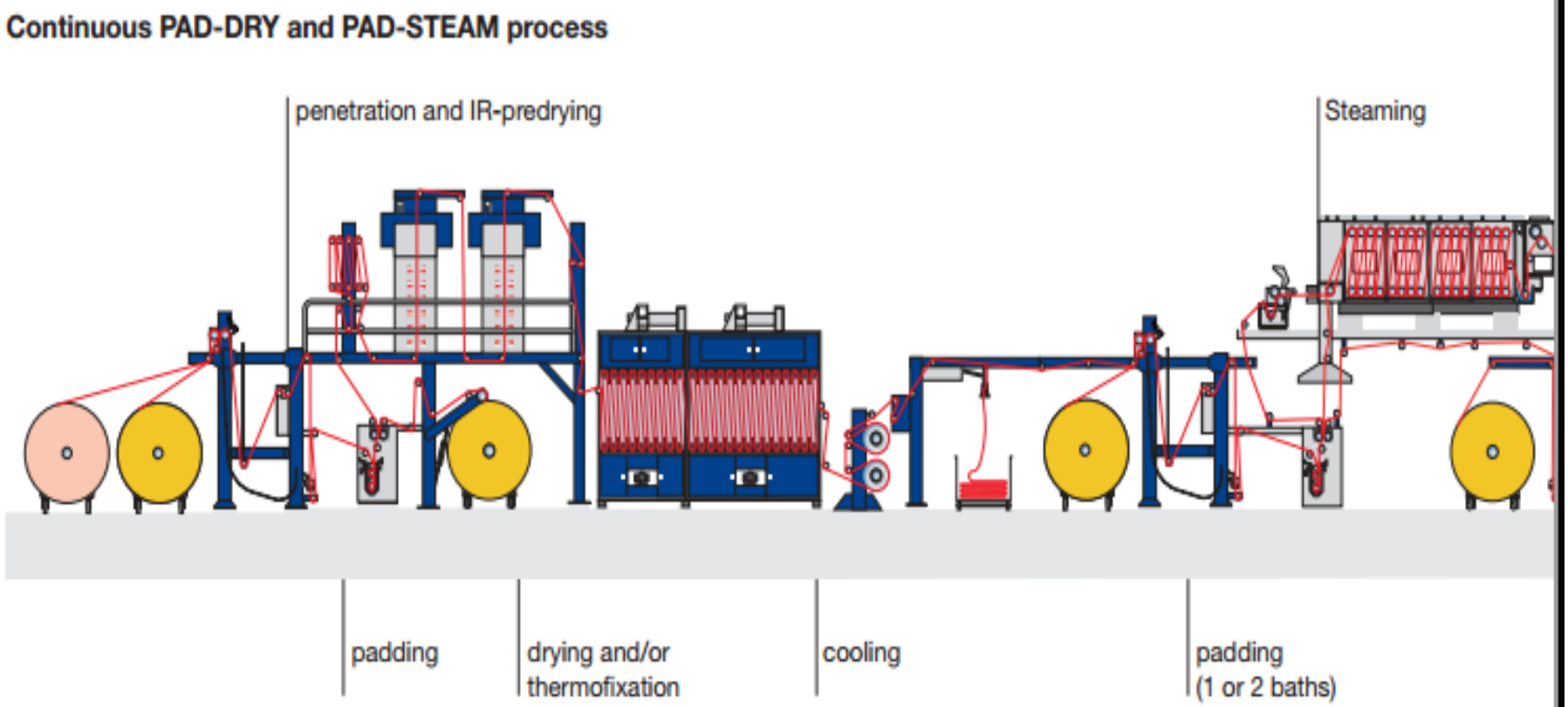
Jig Dyeing

Live steam is injected into the bottom of the dye bath trough a perforated pipe, which runs across the entire width of the dye machine.
Maximum batch size can be as much as several thousand yards of fabric.
Jigs exert considerable lengthwise tension on the fabric and are therefore, more suitable for woven fabrics than for knit fabrics, due to the greater directional stability of wovens.

Flow Diagram



Pad Dyeing


Continuous PAD-DRY and PAD-STEAM process
penetration and IR-predrying
Steaming
padding
drying and/or
thermofixation
cooling
padding
(1 or 2 baths)

Beam Dyeing

- Beam dyeing for piece dyeing is practically identical to beam dyeing used for yarns. The fabric is wound onto a perforated cylinder where the dye bath is forced through the fabric layers. The fabric remains stationary.
- This process is used to dye lightweight, open construction fabrics because the dye bath cannot circulate through a beam of a densely constructed fabric.
- Therefore, beam dyeing is a rapid and economical method for dyeing lightweight, open fabrics.





Garment Dyeing

- Garment dyeing is the dyeing of completed garments. The types of apparel that can be dyed are usually non-tailored and simpler forms, such as sweaters, sweatshirts, T-shirts, hosiery and pantyhose.
- The garments to be dyed are placed in nylon net bags and are loosely packed.
- Paddle machines are usually used for this application. The dye bath is heated by steam injection. The blades on the paddle dip a few centimeters into the dye bath and their rotation stirs the dye bath and pushes the garments down, keeping them submerged in the dye liquor.

Classification of Finishes

Mechanical Finishing:

RAISING: The fabric surface is treated with sharp teeth to lift the surface fibers, resulting in an appearance of fuzziness, softness and warmth.

CALENDARING: The fabric is passed between heated rollers to generate a smooth and polished appearance. The fabric appearance is dependent on roller surface properties and the relative speeds of the rollers.

SHEARING: This process is usually performed on "pile" fabrics. A rotating series of blades cuts the pile/nap to a uniform height. On non-pile fabrics, the shearing process removes any providing fibers/yarns from the fabric surface, giving the fabric surface a smooth appearance.

SINGEING: The fabric is wetted and then passed through an array of gas burners to burn any fibers, neps/pills and loose yarns from the fabric surface.

Classification of Finishes

Chemical Finishing

SANFORIZING: This is both a chemical and mechanical finish. It prevents the fabric from shrinking after production by feeding the fabric between a roller and rubber blanket, so that the rubber blanket compresses the weft (filling) yarns and imparts compressive shrinkage.

CREASE-RESISTANT: A "wash and wear" or "wrinkle-free" finish that is achieved by the addition of a chemical resin finish. When applied to natural fiber fabrics, it gives the fiber a synthetic type of quality.

ANTI-MICROBIAL: A chemical finish which inhibits the growth of microbes.

FLAME RETARDANT: A treatment of the fabric with water, boric acid and borax. This is a temporary finish and the fabric has to be treated after every washing.

Classification of Finishes

SOIL RELEASE: Includes soil resistance, soil release and anti-soil redeposition finish, which allows the fabric to shed the soil gathered during normal washing and eliminates further soil redeposition onto the fabric.

WATER REPELLANT: Similar to a waterproof coating, except it does not coat the entire fabric. The crevices between the warp and weft are left vacant allowing for the air and water vapor to pass through the fabric.

ANTI-PILLING: Alleviates pilling, which are fiber entanglements/balls which are held onto the fabric surface, giving it a rough appearance. Pilling normally occurs on fabrics formed with synthetic spun yarn. The finish suppresses the fibers ability to slacken and reduces the mechanical resistance of the fibers.

ANTI-STATIC: Usually applied to polyester fabrics to prevent dust from clinging to the fabric. The anti-stat finish requires heat treatment to fix to the fabric.

Classification of Finishes

HEAT SETTING: **This process is used in finishing synthetic fabrics. It fixes the fabrics in a relaxed state and helps eliminate subsequent shrinkage and/or creasing. Pre-setting of fabrics allows higher temperatures for setting without the worries of damaging the properties of dyes. It also has a favorable effect on dyeing behavior. Post-setting as a final finish is useful to achieve high dimensional stability and the desired fabric hand.**

Discussion / Questions