

## CHAPTER 21

## TEXTILE PROCESSING PLANTS

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**T**HIS chapter covers (1) basic processes for making synthetic fibers, (2) fabricating synthetic fibers into yarn and fabric, (3) relevant types of HVAC and refrigerating equipment, (4) health considerations, and (5) energy conservation procedures.

Most textile manufacturing processes may be placed into one of three general classifications: synthetic fiber making, yarn making, or fabric making. Synthetic fiber manufacturing is divided into staple processing, tow-to-top conversion, and continuous fiber processing; yarn making is divided into spinning and twisting; and fabric making is divided into weaving and knitting. Although these processes vary, their descriptions reveal the principles on which air-conditioning design for these facilities is based.

### 1. TERMINOLOGY

The following is only a partial glossary of terms used in the textile industry. For more complete terminology, consult the sources in the Bibliography or the Internet search engine of your choice.

**Air permeability.** Porosity, or ease with which air passes through material. Air permeability affects factors such as the wind resistance of sailcloth, air resistance of parachute cloth, and efficiency of various types of air filtration media. It is also a measure of a fabric's warmth or coolness.

**Bidirectional fabric.** A fabric with reinforcing fibers in two directions: in the warp (machine) direction and filling (cross-machine) direction.

**Calender.** A machine used in finishing to impart various surface effects to fabrics. It essentially consists of two or more heavy rollers, sometimes heated, through which the fabric is passed under heavy pressure.

**Denier.** The mass, in grams, of 9000 m of yarn. Denier is a direct numbering system in which lower numbers represent finer sizes and higher numbers the coarser sizes. Outside the United States, the **Tex** system is used instead.

**Heddle.** A cord, round steel wire, or thin flat steel strip with a loop or eye near the center, through which one or more warp threads pass on the loom, so that thread movement may be controlled in weaving. Heddles are held at both ends by the harness frame. They control the weave pattern and shed as the harnesses are raised and lowered during weaving.

**Lubricant.** An oil or emulsion finish applied to fibers to prevent damage during textile processing, or to knitting yarns to make them more pliable.

**Machine direction.** The long direction within the plane of the fabric (i.e., the direction in which the fabric is being produced by the machine).

**Pick.** A single filling thread carried by one trip of the weft insertion device across the loom. Picks interface with the warp ends to form a woven fabric.

**Reed.** A comblike device on a loom that separates the warp yarns and also beats each succeeding filling thread against those already woven. The space between two adjacent wires of the reed is called a **dent**. The fineness of the reed is calculated by the number of dents per inch (per 25.4 mm): the more dents, the finer the reed.

**Selvage.** The narrow edge of woven fabric that runs parallel to the warp. It is made with stronger yarns in a tighter construction than the body of the fabric, to prevent raveling. A **fast selvage** encloses all or part of the picks; a selvage is not fast when the filling threads are cut at the fabric edge after each pick.

**Shuttle.** A boat-shaped device usually made of wood with a metal tip that carries filling yarns through the shed in the weaving process.

**Tex.** The mass, in grams, of 1000 m of fabric. Used primarily outside the United States. *See also Denier.*

**Warp.** The set of yarn in all woven fabrics, running lengthwise and parallel to the selvage, interwoven with the filling.

### 2. FIBER MAKING

Processes preceding fiber extrusion have diverse ventilating and air-conditioning requirements based on principles similar to those that apply to chemical plants.

Synthetic fibers are extruded from metallic spinnerets and solidified as continuous parallel filaments. This process, called **continuous spinning**, differs from the mechanical spinning of fibers or tow into yarn, which is generally referred to as **spinning**.

Synthetic fibers may be formed by melt-spinning, dry-spinning, or wet-spinning. Melt-spun fibers are solidified by cooling the molten polymer; dry-spun fibers by evaporating a solvent, leaving the polymer in fiber form; and wet-spun fibers by hardening the extruded filaments in a liquid bath. The selection of a spinning method is affected by economic and chemical considerations. Generally, nylons, polyesters, and glass fibers are melt-spun; acetates dry-spun; rayons and aramids wet-spun; and acrylics dry- or wet-spun.

For melt- and dry-spun fibers, the filaments of each spinneret are usually drawn through a long vertical tube called a **chimney** or **quench stack**, within which solidification occurs. For wet-spun fibers, the spinneret is suspended in a chemical bath where coagulation of the fibers takes place. Wet-spinning is followed by washing, applying a finish, and drying.

Synthetic continuous fibers are extruded as a heavy denier tow for cutting into short lengths called staple or somewhat longer lengths for tow-to-top conversion, or they are extruded as light denier filaments for processing as continuous fibers. Oil is then applied to lubricate, give antistatic properties, and control fiber cohesion. The extruded filaments are usually drawn (stretched) both to align the molecules along the axis of the fiber and to improve the crystalline

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structure of the molecules, thereby increasing the fiber's strength and resistance to stretching.

Heat applied to the fiber when drawing heavy denier or high-strength synthetics releases a troublesome oil mist. In addition, the mechanical work of drawing generates a high localized heat load. If the draw is accompanied by twist, it is called **draw-twist**; if not, it is called **draw-wind**. After draw-twisting, continuous fibers may be given additional twist or may be sent directly to warping.

When tow is cut to make staple, the short fibers are allowed to assume random orientation. The staple, alone or in a blend, is then usually processed as described in the Cotton System section. However, tow-to-top conversion, a more efficient process, has become more popular. The longer tow is broken or cut to maintain parallel orientation. Most of the steps of the cotton system are bypassed; the parallel fibers are ready for blending and mechanical spinning into yarn.

In the manufacture of glass fiber yarn, light denier multifilaments are formed by attenuating molten glass through platinum bushings at high temperatures and speeds. The filaments are then drawn together while being cooled with a water spray, and a chemical size is applied to protect the fiber. This is all accomplished in a single process prior to winding the fiber for further processing.

### 3. YARN MAKING

The fiber length determines whether spinning or twisting must be used. Spun yarns are produced by loosely gathering synthetic staple, natural fibers, or blends into rope-like form; drawing them out to increase fiber parallelism, if required; and then twisting. Twisted (continuous filament) yarns are made by twisting long monofilaments or multifilaments. Ply yarns are made in a similar manner from spun or twisted yarns.

The principles of mechanical spinning are applied in three different systems: cotton, woolen, and worsted. The cotton system is used for all cotton, most synthetic staple, and many blends. Woolen and worsted systems are used to spin most wool yarns, some wool blends, and synthetic fibers such as acrylics.

#### Cotton System

The cotton system was originally developed for spinning cotton yarn, but now its basic machinery is used to spin all varieties of staple, including wool, polyester, and blends. Most of the steps from raw materials to fabrics, along with the ranges of frequently used humidities, are outlined in Figure 1.

**Opening, Blending, and Picking.** The compressed tufts are partly opened, most foreign matter and some short fibers are removed, and the mass is put in an organized form. Some blending is desired to average the irregularities between bales or to mix different kinds of fiber. Synthetic staple, which is cleaner and more uniform, usually requires less preparation. The product of the picker is pneumatically conveyed to the feed rolls of the card.

**Carding.** This process lengthens the lap into a thin web, which is gathered into a rope-like form called a **sliver**. Further opening and fiber separation follows, as well as partial removal of short fiber and trash. The sliver is laid in an ascending spiral in cans of various diameters.

For heavy, low-count (length per unit of mass) yarns of average or lower quality, the card sliver goes directly to drawing. For lighter, high-count yarns requiring fineness, smoothness, and strength, the card sliver must first be combed.

**Lapping.** In sliver lapping, several slivers are placed side by side and drafted. In ribbon lapping, the resulting ribbons are laid one on another and drafted again. The doubling and redoubling averages out sliver irregularities; drafting improves fiber parallelism. Some recent processes lap only once before combing.

**Combing.** After lapping, the fibers are combed with fine metal teeth to substantially remove all fibers below a predetermined

length, to remove any remaining foreign matter, and to improve fiber arrangement. The combed lap is then attenuated by drawing rolls and again condensed into a single sliver.

**Drawing.** Drawing follows either carding or combing and improves uniformity and fiber parallelism by doubling and drafting several individual slivers into a single composite strand. Doubling averages the thick and thin portions; drafting further attenuates the mass and improves parallelism.

**Roving.** Roving continues the processes of drafting and paralleling until the strand is a size suitable for spinning. A slight twist is inserted, and the strand is wound on large bobbins used for the next roving step or for spinning.

**Spinning.** Mechanical spinning simultaneously applies draft and twist. The packages (any form into or on which one or more ends can be wound) of roving are creeled at the top of the frame. The unwinding strand passes progressively through gear-driven drafting rolls, a yarn guide, the C-shaped traveler, and then to the bobbin. The vertical traverse of the ring causes the yarn to be placed in predetermined layers.

The difference in peripheral speed between the back and front rolls determines the draft. Twist is determined by the rate of front roll feed, spindle speed, and drag, which is related to the traveler mass.

The space between the nip or bite of the rolls is adjustable and must be slightly greater than the longest fiber. The speeds of front

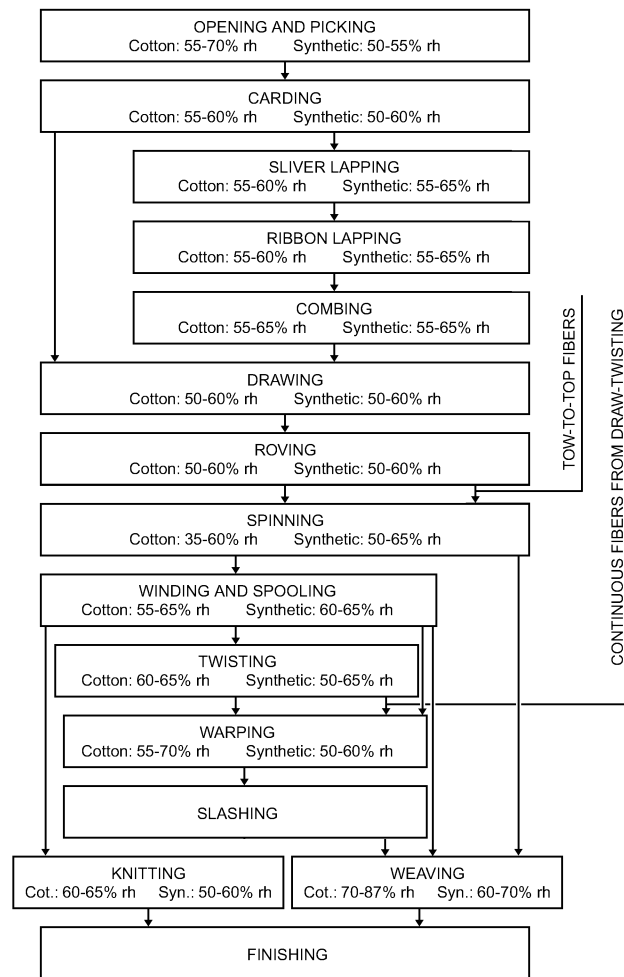


Fig. 1 Textile Process Flowchart and Ranges of Humidity

and back rolls are independently adjustable. Cotton spindles normally run at 8000 to 9000 rpm but may exceed 14 000 rpm. In ring twisting, drawing rolls are omitted, and a few spindles run as high as 18 000 rpm.

Open-end or turbine spinning combines drawing, roving, lapping, and spinning. Staple fibers are fragmented as they are drawn from a sliver and fed into a small, fast-spinning centrifugal device. In this device, the fibers are oriented and discharged as yarn; twist is imparted by the rotating turbine. This system is faster, quieter, and less dusty than ring spinning.

Spinning is the final step in the cotton system; the feature that distinguishes it from twisting is the application of draft. The amount and point of draft application accounts for many of the subtle differences that require different humidities for apparently identical processes.

**Atmospheric Conditions.** From carding to roving, the loosely bound fibers are vulnerable to static electricity. In most instances, static can be adequately suppressed with humidity, which should not be so high as to cause other problems. In other instances, it is necessary to suppress electrostatic properties with antistatic agents. Wherever draft is applied, constant humidity is needed to maintain optimum frictional uniformity between adjacent fibers and, hence, cross-sectional uniformity.

### Woolen and Worsted Systems

The woolen system generally makes coarser yarns, whereas the worsted system makes finer ones of a somewhat harder twist. Both may be used for lighter blends of wool, as well as for synthetic fibers with the characteristics of wool. The machinery used in both systems applies the same principles of draft and twist but differs greatly in detail and is more complex than that used for cotton.

Compared to cotton, wool fibers are dirtier, greasier, and more irregular. They are scoured to remove grease and are then usually reimpregnated with controlled amounts of oil to make them less hydrophilic and to provide better interfiber behavior. Wool fibers are scaly and curly, so they are more cohesive and require different treatment. Wool, in contrast to cotton and synthetic fibers, requires higher humidities in the processes prior to and including spinning than it does in the processes that follow. Approximate humidities are given in Kirk and Othmer (1993).

### Twisting Filaments and Yarns

Twisting was originally applied to silk filaments; several filaments were doubled and then twisted to improve strength, uniformity, and elasticity. Essentially the same process is used today, but it is now extended to spun yarns, as well as to single or multiple filaments of synthetic fibers. Twisting is widely used in the manufacture of sewing thread, twine, tire cord, tufting yarn, rug yarn, ply yarn, and some knitting yarns.

Twisting and doubling is done on a **down-** or **ring-twister**, which draws in two or more ends from packages on an elevated creel, twists them together, and winds them into a package. Except for the omission of drafting, down-twisters are similar to conventional ring-spinning frames.

When yarns are to be twisted without doubling, an **up-twister** is used. Up-twisters are primarily used for throwing synthetic monofilaments and multifilaments to add to or vary elasticity, light reflection, and abrasion resistance. As with spinning, yarn characteristics are controlled by making the twist hard or soft, right (S) or left (Z). Quality is determined largely by the uniformity of twist, which, in turn, depends primarily on the tension and stability of the atmospheric conditions (Figure 1). Because the frame may be double- or triple-decked, twisting requires concentrations of power. The frames are otherwise similar to those used in spinning, and they present the same air distribution problems. In twisting, lint is not a serious problem.

## 4. FABRIC MAKING

### Preparatory Processes

When spinning or twisting is complete, the yarn may be prepared for weaving or knitting by processes that include winding, spooling, creeling, beaming, slashing, sizing, and dyeing. These processes have two purposes: (1) to transfer the yarn from the type of package dictated by the preceding process to a type suitable for the next and (2) to impregnate some of the yarn with sizes, gums, or other chemicals that may not be left in the final product.

**Filling Yarn.** Filling yarn is wound on quills for use in a loom shuttle. It is sometimes predyed and must be put into a form suitable for package or skein dyeing before it is quilled. If the filling is of relatively hard twist, it may be put through a twist-setting or conditioning operation in which internal stresses are relieved by applying heat, moisture, or both.

**Warp Yarn.** Warp yarn is impregnated with a transient coating of size or starch that strengthens the yarn's resistance to the chafing it will receive in the loom. The yarn is first rewound onto a cone or other large package from which it will unwind speedily and smoothly. The second step is warping, which rewinds a multiplicity of ends in parallel arrangement on large spools, called **warp or section beams**. In the third step, slashing, the threads pass progressively through the sizing solution, through squeeze rolls, and then around cans, around steam-heated drying cylinders, or through an air-drying chamber. A thousand kilograms or more may be wound on a single loom beam.

**Knitting Yarn.** If hard-spun, knitting yarn must be twist-set to minimize kinking. Filament yarns must be sized to reduce strip-backs and improve other running qualities. Both must be put in the form of cones or other suitable packages.

Uniform tension is of great importance in maintaining uniform package density. Yarns tend to hang up when unwound from a hard package or slough off from a soft one, and both tendencies are aggravated by spottiness. The processes that require air conditioning, along with recommended relative humidities, are presented in Figure 1.

### Weaving

In the simplest form of weaving, harnesses raise or depress alternate warp threads to form an opening called a **shed**. A shuttle containing a quill is kicked through the opening, trailing a thread of filling behind it. The lay and the reed then beat the thread firmly into one apex of the shed and up to the fell of the previously woven cloth. Each shuttle passage forms a pick. These actions are repeated at frequencies up to five per second.

Each warp thread usually passes through a drop-wire that is released by a thread break and automatically stops the loom. Another automatic mechanism inserts a new quill in the shuttle as the previous one is emptied, without stopping the loom. Other mechanisms are actuated by filling breaks, improper shuttle boxing, and the like, which stop the loom until it is manually restarted. Each cycle may leave a stop mark sufficient to cause an imperfection that may not be apparent until the fabric is dyed.

Beyond this basic machine and pattern are many complex variations in harness and shuttle control, which result in intricate and novel weaving effects. The most complex loom is the **jacquard**, with which individual warp threads may be separately controlled. Other variations appear in looms for such products as narrow fabrics, carpets, and pile fabrics. In the **Sulzer weaving machine**, a special filling carrier replaces the conventional shuttle. In the rapier, a flat, spring-like tape uncoils from each side and meets in the middle to transfer the grasp on the filling. In the **water jet loom**, a tiny jet of high-pressure water carries the filling through the shed of the warp. Other looms transport the filling with compressed air.

High humidity increases the abrasion resistance of the warp. Weave rooms require 80 to 85% humidity or higher for cotton and up to 70% humidity for synthetic fibers. Many looms run faster when room humidity and temperature are precisely controlled.

In the weave room, power distribution is uniform, with an average concentration somewhat lower than in spinning. The rough treatment of fibers liberates many minute particles of both fiber and size, thereby creating considerable amounts of airborne dust. In this high-humidity area, air changes average from four to eight per hour. Special provisions must be made for maintaining conditions during production shutdown periods, usually at a lower relative humidity.

### Knitting

Typical knitted products are seamless articles produced on circular machines (e.g., undershirts, socks, and hosiery) and those knitted flat (e.g., full-fashioned hosiery, tricot, milanese, and warp fabrics).

Knitted fabric is generated by forming millions of interlocking loops. In its simplest form, a single end is fed to needles that are actuated in sequence. In more complex constructions, hundreds of ends may be fed to groups of elements that function more or less in parallel.

Knitting yarns may be either single strand or multifilament and must be of uniform high quality and free from neps or knots. These yarns, particularly the multifilament type, are usually treated with special sizes to provide lubrication and to keep broken filaments from stripping back.

The need for precise control of yarn tension, through controlled temperature and relative humidity, increases with the fineness of the product. For example, in finer gages of full-fashioned hosiery, a 1 K change in temperature is the limit, and a 10% change in humidity may change the length of a stocking by 75 mm. For knitting, desirable room conditions are approximately 24°C db and 45 to 65% rh.

### Dyeing and Finishing

Finishing, which is the final readying of a mill product for its particular market, ranges from cleaning to imparting special characteristics. The specific operations involved vary considerably, depending on the type of fiber, yarn, or fabric, and the end product usage. Operations are usually done in separate plants. These areas need not only normal heating, ventilation, and fog removal systems, but also removal of hot, dusty, and toxic fumes from continuous ovens and tenters. Packaged chilling equipment is sometimes used to control temperatures of preshrink chemicals, dyes, and coatings that are applied to textiles and yarns before finishing. Some of these processes require corrosive-resistant materials and equipment.

Inspection is the only finishing operation to which air conditioning is regularly applied, although most of the others require ventilation. Finishing operations that use wet processes usually keep their solutions at high temperatures and require special ventilation to prevent destructive condensation and fog. Spot cooling of workers may be necessary for large releases of sensible, latent, or radiant heat.

## 5. AIR-CONDITIONING DESIGN

There are many diverse and special needs of specific areas of the textile process. Generally, a meeting with the owner's representative(s), local code officials, and the owner's insurance company is helpful in satisfying the particular requirements of the process, insurance companies, and local officials. HVAC engineers designing textile projects need to have a thorough understanding of the following HVAC system elements:

- Psychrometric process in spray systems
- Humidification and dehumidification
- Draft-free air distribution
- Fog control
- Water and air filters

- Dust collectors
- Industrial ductwork
- Large built-up air handlers
- Large water chillers
- Cooling towers
- Industrial piping systems
- Pumping
- Corrosion-resistant metallurgy
- Large centrifugal air compressors
- Programmable logic controllers and supervisory control and data acquisition (SCADA) systems
- Water treatment in open sump systems

Consultation with mechanical contracting companies experienced with building and installing textile-related systems provides great insight to these attributes. Thorough understanding of the processes to be conditioned; precise calculations; familiarity with codes, regulations, and current industry standards; as well as reasonable owner/engineer/contractor relationships and adherence to the owner's budget are necessary for successful projects.

Air washers are especially important in textile manufacturing and may be either conventional low-velocity or high-velocity units in built-up systems. Unitary high-velocity equipment using rotating eliminators, although no longer common, is still found in some plants.

Contamination of air washers by airborne oils often dictates the separation of air washers and process chillers by heat exchangers, usually of the plate or frame type.

### Open-Sump Chilled-Water Systems

It is common practice to use open sumps in textile processing with air washer air-handling units. Open sumps present a unique problem for the removal of lint from the basins. Many systems return the air from spinning areas, and this air carries lint and free fibers from the spinning process. These fibers are typically not completely removed by central collectors (see Figure 3). In older facilities, the central collectors may be totally ineffective or nonexistent. A rotating drum filter is commonly used to remove lint fibers from the sumps of air washers to prevent clogging of spray nozzles and fouling of spray media. The rotating drum filters are semisubmerged in the sump and are fitted with a vacuum system that traverses the part of the drum that is exposed to air, removing the lint from the drum surface and transporting it through a high-pressure blower to a bag house, where water is separated and the lint collected for future disposal.

Many textile plants have an open sump for return of chilled water from the air washers (see A in Figure 2). The chilled-water pumps draw out of these sumps through a screened inlet, C, for return of chilled water to the chillers. In designing the inlet screen, care must be taken to avoid a configuration that might lead to pump cavitation. Rotating drum filters should also be considered for these sumps to prevent fouling of chiller tubes by lint that passes the screens. These sumps must be carefully sized to receive the volume of water contained in the system when the air washers are shut off and their sumps drain down.

### Integrated Systems

Many mills use a refined air washer system that combines the air-conditioning system and the collector system (see the section on Collector Systems) into an integrated unit. Air handled by the collector system fans and any air required to make up total return air are delivered back to the air-conditioning apparatus through a central duct. The quantity of air returned by individual yarn-processing machine cleaning systems must not exceed the air-conditioning supply air quantity. Air discharged by these individual suction systems is carried by return air ducts directly to the air-conditioning system. Before entering the duct, some of the cleaning system air

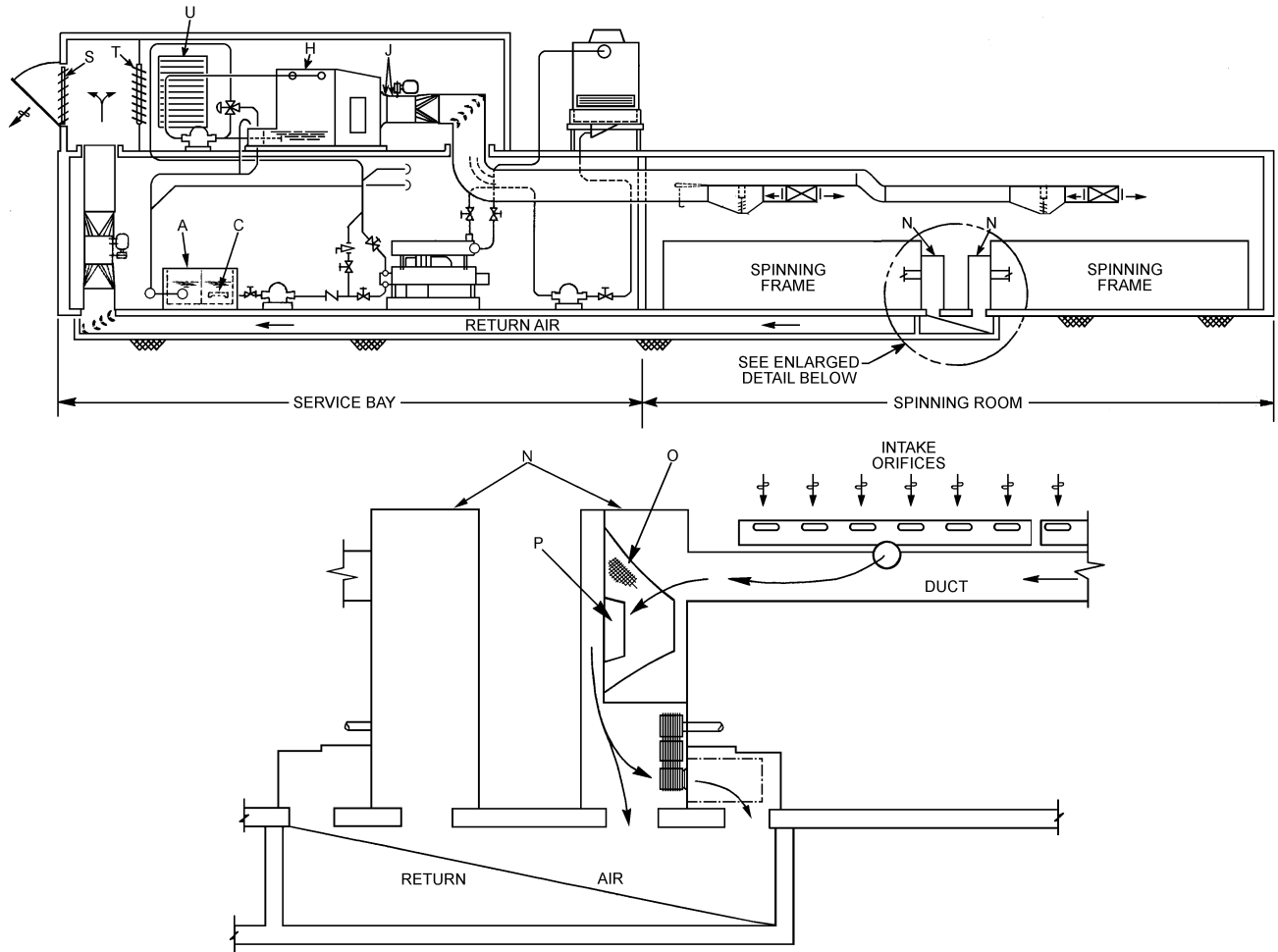


Fig. 2 Mechanical Spinning Room with Combined Air-Conditioning and Collector System

passes over the yarn-processing machine drive motor and through a special enclosure to capture heat losses from the motor.

When integrated systems occasionally exceed the supply air requirements of the area served, the surplus air must be reintroduced after filtering.

Individual suction cleaning systems that can be integrated with air conditioning are available for cards, drawing frames, lap winders, combers, roving frames, spinning frames, spoolers, and warpers. The following advantages result from this integration:

- With a constant air supply, the best uniform air distribution can be maintained year-round.
- Downward airflow can be controlled; crosscurrents in the room are minimized or eliminated; drift or fly from one process to another is minimized or eliminated. Room partitioning between systems serving different types of manufacturing processes further enhances the value of this integration by controlling room air pattern year-round.
- Heat losses of the yarn-processing frame motor and any portion of the processing frame heat captured in the duct, as well as the heat of the collector system equipment, cannot affect room conditions; hot spots in motor alleys are eliminated, and although this heat goes into the refrigeration load, it does not enter the room. As a result, the supply air quantity can be reduced.

- Uniform conditions in the room improve production; conditioned air is drawn directly to the work areas on the machines, minimizing or eliminating wet or dry spots.
- Maximum cleaning use is made of the air being moved. A guide for cleaning air requirements follows:

Pickers	1200 to 1900 L/s per picker
Cards	300 to 700 L/s per card
Spinning	2 to 4 L/s per spindle
Spooling	19 L/s per spool

### Collector Systems

A collector system is a waste-capturing device that uses many orifices operating at high suction pressures. Each piece of production machinery is equipped with suction orifices at all points of major lint generation. The captured waste is generally collected in a fan and filter unit located either on each machine or centrally to accept waste from a group of machines.

A collector in the production area may discharge waste-filtered air either back into the production area or into a return duct to the air-conditioning system. It then enters the air washer or is relieved through dampers to the outdoors.

Figure 2 shows a mechanical spinning room with air-conditioning and collector systems combined into an integrated unit. In this case, the collector system returns all of its air to the air-conditioning

system. If supply air from the air-conditioning system exceeds the maximum that can be handled by the collector system, additional air should be returned by other means.

Figure 2 also shows return air entering the air-conditioning system through damper T, passing through air washer H, and being delivered by fan J to the supply duct, which distributes it to maintain conditions within the spinning room. At the other end of each spinning frame are unitary filter-collectors consisting of enclosure N, collector unit screen O, and collector unit fan P.

Collector fan P draws air through the intake orifices spaced along the spinning frame. This air passes through the duct that runs lengthwise to the spinning frame, passes through screen O, and is then discharged into the enclosure base (beneath the fan and screen). The air quantity is not constant; it drops slightly as material builds up on the filter screen.

Because the return air quantity must remain constant, and the air quantity discharged by fan P is slightly reduced at times, relief openings are necessary. Relief openings also may be required when the return air volume is greater than the amount of air the collector suction system can handle.

The discharge of fan P is split, so part of the air cools the spinning frame drive motor before rejoining the rest of the air in the return air tunnel. Regardless of whether the total return air quantity enters the return air tunnel through collector units, or through a combination of collector units and floor openings beneath spinning frames, return air fan R delivers it into the apparatus, ahead of return air damper T. Consideration should be given to filtering the return air prior to its delivery into the air-conditioning apparatus.

Mild-season operation causes more outdoor air to be introduced through damper U. This air is relieved through motorized damper S, which opens gradually as outdoor damper U opens, while return damper T closes in proportion. All other components perform as typical central station air-washer systems.

A system having the general configuration shown in Figure 2 may also be used for carding; the collector system portion of this arrangement is shown in Figure 3. A central collector filters the lint-laden air taken from multiple points on each card. This air is discharged to return air duct A and is then either returned to the air-conditioning system, exhausted outdoors, or returned directly to the room. A central collector filter may also be used with the spinning room system of Figure 2.

### Air Distribution

Textile plants served by generally uniform air distribution may still require special handling for areas of load concentration.

**Continuous Spinning Area.** Methods of distribution are diverse and generally not critical. However, spot cooling or localized heat removal may be required. This area may be cooled by air conditioning, evaporative cooling, or ventilation.

**Chimney (Quench Stack).** Carefully controlled and filtered air or other gas is delivered to the chimneys; it is returned for

conditioning and recovery of any valuable solvents present. Distribution of the air is of the utmost importance. Nonuniform temperature, humidity, or airflow disturbs the yarn, causing variations in fiber diameter, crystalline structure, and orientation. A fabric made of such fibers streaks when dyed.

In melt spinning, the solvent concentration in the chimney air must be maintained below its explosive limit. Care is still required to prevent vapors from being ignited by a spark or flame. The air-conditioning system must be reliable, because interruption of the spinning causes the solution to solidify in the spinnerets.

**Wind-Up or Take-Up Areas of Continuous Spinning.** A heavy air-conditioning load is developed. Air is often delivered through branch ducts alongside each spinning machine. Low-velocity, low-aspiration diffusers must be sized not to agitate delicate fibers.

**Draw-Twist or Draw-Wind Areas of Fiber Manufacture.** A heavy air-conditioning load is developed. Distribution, diffusion, and return systems are similar to those for the continuous spinning take-up area.

**Opening and Picking.** Usually, opening and picking require only a uniform distribution system. The area is subject to shutdown of machinery during portions of the day. Generally, an all-air system with independent zoning is installed.

**Carding.** A uniform distribution system is generally installed. There should be little air movement around the web in cotton carding. Central lint collecting systems are available but must be incorporated into the system design. An all-air system is often selected for cotton carding.

In wool carding, there should be less air movement than in cotton carding, not only to avoid disturbing the web, but also to reduce cross-contamination between adjacent cards. This is because different colors of predyed wool may be run side by side on adjacent cards. A split system (i.e., separate systems for each card) may be considered for wool carding to reduce air movement. The method of returning air is also critical for achieving uniform conditions.

**Drawing and Roving.** Generally, a uniform distribution all-air system works well.

**Mechanical Spinning Areas.** A heavy air-conditioning load is generated, consisting of spinning frame power uniformly distributed along the frame length and frame driver motor losses concentrated in the motor alley at one end of the frame.

Supply air ducts should run across the frames at right angles. Sidewall outlets between each of the two adjacent frames then direct the supply air down between the frames, where conditions must be maintained. Where concentrated heat loads occur, as in a double motor alley, placement of a supply air duct directly over the alley should be considered. Sidewall outlets spaced along the bottom of the duct diffuse air into the motor alley.

The collecting system, whether unitary or central, with intake points distributed along the frame length at the working level, assists in pulling supply air down to the frame, where maintenance of conditions is most important. A small percentage of the air handled by a central collecting system may be used to convey the collected lint and yarn to a central point, thus removing that air from the spinning room.

Machine design in spinning systems sometimes requires interfloor air pressure control.

**Winding and Spooling.** Generally, a uniform distribution, all-air system is used.

**Twisting.** This area has a heavy air-conditioning load. Distribution considerations are similar to those in spinning. Either all-air or split systems are installed.

**Warping.** This area has a very light load. Long lengths of yarn may be exposed unsupported in this area. Generally, an all-air system with uniform distribution is installed. Diffusers may be of the low-aspiration type. Return air is often near the floor.

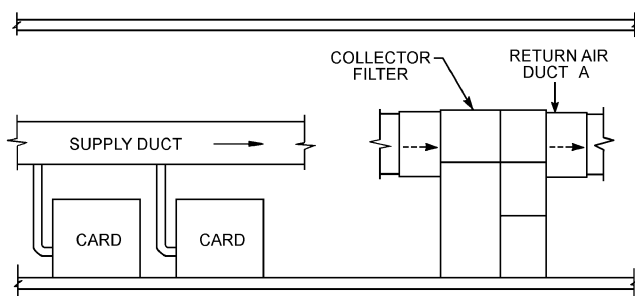


Fig. 3 Central Collector for Carding Machine

**Weaving.** Generally, a uniform distribution system is necessary. Synthetic fibers are more commonly woven than natural fibers. The lower humidity requirements of synthetic fibers allow the use of an all-air system rather than the previously common split system. When lower humidity is coupled with the water jet loom, a high latent load results.

### Health Considerations

For detailed information on control of industrial contaminants, see Chapter 29 of the 2012 *ASHRAE Handbook—HVAC Systems and Equipment*.

**Control of Oil Mist.** When textiles coated with lubricating oils are heated above 93°C in drawing operations in ovens, heated rolls, tenterframes, or dryers, an oil mist is liberated. If the oil mist is not collected at the source of emission and disposed of, a slightly odorous haze results.

Various devices have been proposed to separate oil mist from the exhaust air, such as fume incinerators, electrostatic precipitators, high-energy scrubbers, absorption devices, high-velocity filters, and condensers.

Spinning operations that generate oil mist must be provided with a high percentage (30 to 75%) of outdoor air. In high-speed spinning, 100% outdoor air is commonly used.

Operations such as drum cooling and air texturizing, which could contaminate the air with oil, require local exhausts.

**Control of Monomer Fumes.** Separate exhaust systems for monomers are required, with either wet- or dry-type collectors, depending on the fiber being spun. For example, caprolactam nylon spinning requires wet exhaust scrubbers.

**Control of Hazardous Solvents.** Provisions must be made for the containment, capture, and disposal of hazardous solvents.

**Control of Cotton Dust.** Byssinosis, also known as brown or white lung disease, is believed to be caused by a histamine-releasing substance in cotton, flax, and hemp dust. In the early stages of the disease, a cotton worker returning to work after a weekend experiences difficulty in breathing that is not relieved until later in the week. After 10 to 20 years, the breathing difficulty becomes continuous; even leaving the mill does not provide relief.

The U.S. Department of Labor enforces an OSHA standard of lint-free dust. The most promising means of control are improved exhaust procedures and filtration of recirculated air. Lint particles are 1 to 15 µm in diameter, so filtration equipment must be effective in this size range. Improvements in carding and picking that leave less trash in the raw cotton also help control lint.

**Noise Control.** The noise generated by HVAC equipment can be significant, especially if the textile equipment is modified to meet present safety criteria. For procedures to analyze and correct the noise from ventilating equipment, see [Chapter 48](#).

### Safety and Fire Protection

**Special Warning:** Certain industrial spaces may contain flammable, combustible, and/or toxic concentrations of vapors or dusts under either normal or abnormal conditions. In spaces such as these, there are life-safety issues that this chapter may not completely address. Special precautions must be taken in accordance with requirements of recognized authorities such as the National Fire Protection Association (NFPA), the Occupational Safety and Health Administration (OSHA), and the American National Standards Institute (ANSI). In all situations, engineers, designers, and installers who encounter conflicting codes and standards must defer to the code or standard that best addresses and safeguards life safety.

Oil mist can accumulate in ductwork and create a fire hazard. Periodic cleaning reduces the hazard, but provisions should be made to contain a fire with suppression devices such as fire-activated dampers and interior duct sprinklers.

## 6. ENERGY CONSERVATION

The following are some steps that can be taken to reduce energy consumption:

- Applying heat recovery to water and air
- Automating high-pressure dryers to save heat and compressed air
- Decreasing hot-water temperatures and increasing chilled-water temperatures for rinsing and washing in dyeing operations
- Replacing running washes with recirculating washes where practical
- Changing double-bleaching procedures to single-bleaching where practical
- Eliminating rinses and final wash in dye operations where practical
- Drying by “bump and run” process
- Modifying drying or curing oven air-circulation systems to provide counterflow
- Using energy-efficient electric motors and textile machinery
- For drying operations, using discharge air humidity measurements to control the exhaust versus recirculation rates in full economizer cycles

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