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Humidification for Textile Mills

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India has a rich and glorious tradition in textiles along with natural advantages of indigenous cotton crop, large pool of skilled man power and a well diversified manufacturing base with access to a net-work of 'R & D', design and testing institutions.

Indian textile industry has nearly one-third of the world's loomage and the country is now recognized as the third largest producer of cotton and cotton yarn in the world.

With the lifting of quota based curbs on textile exports to the U.S and European markets effective January 1, 2005, Indian textile entrepreneurs are gearing up to expand the export base of value added products through technology upgradation, modernization of textile processes and machinery and focus on quality improvement for sustaining their competitiveness in the global arena.

Textile Manufacturing Processes

(Raw cotton --> Fibre making --> Yarn making (spinning) --> Fabric making (weaving / knitting)

The sequential steps during the processes of fibre making , yarn making and fabric making in the production of textiles along with the required relative humidity conditions to be maintained at each stage of processing are shown in the textile process flow chart diagram, **Figure 1**. Cotton textile processing from the initial stage of opening and picking upto the final stage of yarn-making (spinning) and the post-spinning phases culminating in fabric making (knitting or weaving) are as follows:

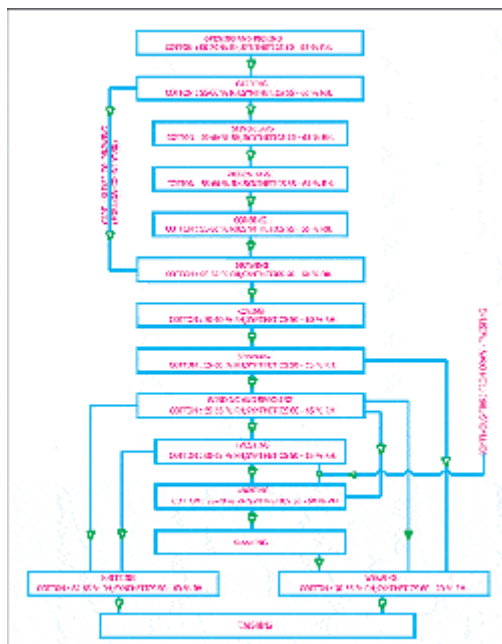


Figure 1 : Textile process flow chart and range of humidity.

Opening, Blending & Picking

These operations are carried out in the blow room. Compressed tufts of raw cotton are partly opened to remove foreign matter and some short fibres. Some blending is done to even out non-uniformity in the mass contained in different bales.

Product of the picker from blow-room is pneumatically conveyed to the feed rolls of the 'cards' in the 'carding' section.

Carding

This process elongates the lap of cotton into a thin web which is gathered into a rope like form called a 'sliver'. Further opening, fibre-separation and partial removal of short fibres and trash is done here. The 'sliver' is collected in an ascending spiral in cans of various diameters.

For heavy low-count (length per unit of mass) yarns of average quality, the 'card sliver' goes directly for drawing' operation.

For lighter, high-count yarns requiring fineness, smoothness and strength, the card sliver goes through sliver lapping / ribbon lapping and combing before 'drawing'



Laps Formation

In the process of sliver lapping the slivers are placed side by side and drafted (stretched) to improve fibre parallelism before combing.

In case of ribbon lapping the ribbons are laid one on another and drafted again to improve fibre-parallelism.

Combing

After lapping, the fibres are combed with fine metal teeth to substantially remove all fibres below a predetermined length as well as remove remaining foreign matter and improve fibre orientation.



Photo 3 : Comber

Drawing

The combed lap then goes through drawing rolls to improve fibre uniformity and parallelism and several individual slivers are drafted into a single composite strand.

Roving

Continues the process of drafting to improve parallelism until the strand attains a size suitable for spinning'. The strand is wound on large bobbins for the next step of 'spinning'



Spinning

Spinning is the final step of yarn making in the cotton system. Mechanized spinning imparts both draft and twist to the yarn.

The packages of roving are creeled at the top of the spinning frame. The unwinding strand passes in sequence through gear-driven drafting rolls (which imparts the necessary draft to the yarn due to difference in surface speed of back and front rolls), a yarn guide, C-shaped traveler and then to the 'bobbin'. Vertical traverse of the ring causes the yarn to be placed in pre-determined layers.



Photo 5 : Ring frames (spinning)

Open-end Spinning

Open-end spinning machines combine operations of lapping, roving and spinning in a single unit.

Staple fibres are fragmented as these are drawn from a 'sliver' and fed into a small, fast spinning centrifugal device in which the fibres are oriented and discharged after twisting the yarn by the 'rotating turbine'

Twisting

In this process several filaments are doubled and then twisted to improve strength, uniformity and elasticity. This process is used in the manufacture of sewing thread, twine, tyre cord, rug yarn and some knitting yarns.

Twisting and doubling is done on a ring-twister which is quite similar to a ring spinning frame. Quality depends on uniformity of twist for which stability of tension as well as stable relative humidity conditions are necessary.

Fabric Making

When spinning / twisting is complete, the yarn is prepared for weaving or knitting by preparatory processes like winding and spooling, warping and slashing.

The yarn is wound on quills for use in a loom shuttle.



Photo 6 : Winding

Warping of Yarn

Warp-yarn is provided with a coating of sizing chemical or starch to improve the yarn's resistance to 'chaffing' that takes place in the weaving loom. The yarn is first wound on a cone and then rewound on large spools called 'warp' or section beams. The next step is slashing in which the threads pass through a sizing solution, through squeeze rolls and then around cans, and steam-heated drying cylinders or air drying chamber.

Knitting Yarn

The knitting yarn after twist-set (to remove kinks) is put into the form of cones or other forms of packages. Knitted fabrics are produced on circular machines by providing uniform tension so as to maintain uniform package density. Precise control of yarn tension for knitting operation, particularly for hosiery products, generally requires precise control on temperature and humidity conditions (recommended inside design conditions $25 \pm 1.1^{\circ}\text{C}$ and $55\% \pm 5\% \text{RH}$.)



Photo 7 : Knitting

Weaving

Modern weaving looms have advanced much ahead of the basic harness (for raising or depressing alternate warp threads to form an opening) and control of movement of shuttle with quill at slow frequencies (5 per second) through the opening for filling the threads in place.

Complex looms like 'Jacquard' separately control individual warp threads to produce intricate weaving patterns. In the Sulzer weaving machine, a special filling carrier replaces the conventional shuttle.

In water jet looms, tiny jets of high pressure water carry the filling through the shed of the warp. In air jet looms the filling is carried with compressed air.

The process of weaving liberates many fibre particles which creates air borne fibre-fly (fluff) which are generally carried by the return air through return air trenches for exhaust or recirculation after cleaning by rotary return air filters.



Photo 8 : Weaving

Role of Humidity in the Textile Process

From 'carding' till 'roving', the loosely bound fibres are vulnerable to static electricity in dry and brittle condition due to static and dynamic friction. This also creates dust and fibre fly (fluff) . Higher moisture content lowers the insulation resistance and helps to carry off the electrostatic charge. Hence relative humidity (being related to moisture content) needs to be maintained above the lower limit of relative humidity range, specified in **Figure 1** for various textile processes so as to avoid the problems of yarn breakage in dry and brittle condition and also minimize the build up of static charge so as to reduce dust and fibre fly (fluff).

Above the high moisture limit (i.e. above the upper limit of relative humidity for the process) fibres tend to stick and lead to formation of laps on the rolls which disrupts the production process. Removal of laps is a manual and time consuming process.

Weaving rooms for cotton fabric making are designed to maintain high relative humidity of 80% to 85% at the warp sheet level i.e. at 'loomsphere' as high humidity helps to increase the abrasion resistance of the warp. Whereas it would suffice to maintain general humidity condition in the room at around 65% R.H.

Knitting operation also requires a stable relative humidity condition at $55\% \pm 5\%$ for precise control of yarn tension.

Hence it is important to maintain stable relative humidity conditions within the prescribed tolerance limits at all steps of textile processing.

Impact of Temperature

Mechanical properties of fibres and yarns also depend on the surrounding temperature conditions to which these are exposed during the textile process.

Due to high heat dissipation from spinning as well as weaving and knitting equipment there is a significant increase in temperature conditions particularly in the vicinity of the machinery and their driving motors.

The natural wax covering cotton fibres softens at these raised temperature conditions, thereby adversely affecting the lubricating property of wax for controlling static and dynamic friction. Increase in temperature beyond the design limit also reduces the relative humidity condition near the processing elements of the machinery. Hence textile air-engineering design has to take care of controlled air flow within the textile machinery for dissipating heat generated at the source and it is customary to carry the waste heat along with the return air to the return air trench. The quantity of return air going to exhaust or recirculation is regulated for controlling the inside design conditions. Modern spinning equipment is designed to operate at high spindle speed. However high ambient temperature always tends to curtail the speed limit of operation. Moreover, the sophisticated electronic controls in modern textile machinery also require that inside temperature in the department should not exceed 33°C or so.

It is also necessary to limit the range of temperature to which the textile machinery is exposed, since the structure of the machinery containing many steel and aluminum parts which expand at different rates with temperature rise (due to difference in co-efficient of thermal expansion) will be subjected to mechanical stress.

Hence, along with maintenance of stable relative humidity conditions recommended for different textile processes, it is also desirable to maintain the temperature level within a range, without fluctuation.

Inside Dry Bulb Temperature Conditions

In a typical application of a textile mill humidification system at a location in western Maharashtra, with summer outside design conditions of 40°C dry bulb and 25°C wet bulb temperature, adiabatic cooling of outside air in summer by humidification in an air washer with 95% saturation efficiency and supply of this humidified air will attain the following inside temperature conditions in respective departments corresponding to the desired inside relative humidity conditions specified.

The adiabatic cooling process and the inside temperature and relative humidity conditions are plotted in the psychrometric chart **Figure 2** for further understanding:

Air temperature leaving the air washer = $40 - (40 - 25) \times 0.95 = 40 - 14.25 = 25.75^\circ\text{C}$.

With change in ambient air wet bulb temperature, the air-temperature leaving the air washer will also vary along with a change in the department's inside dry bulb temperature, even though the inside design relative humidity condition remains constant.

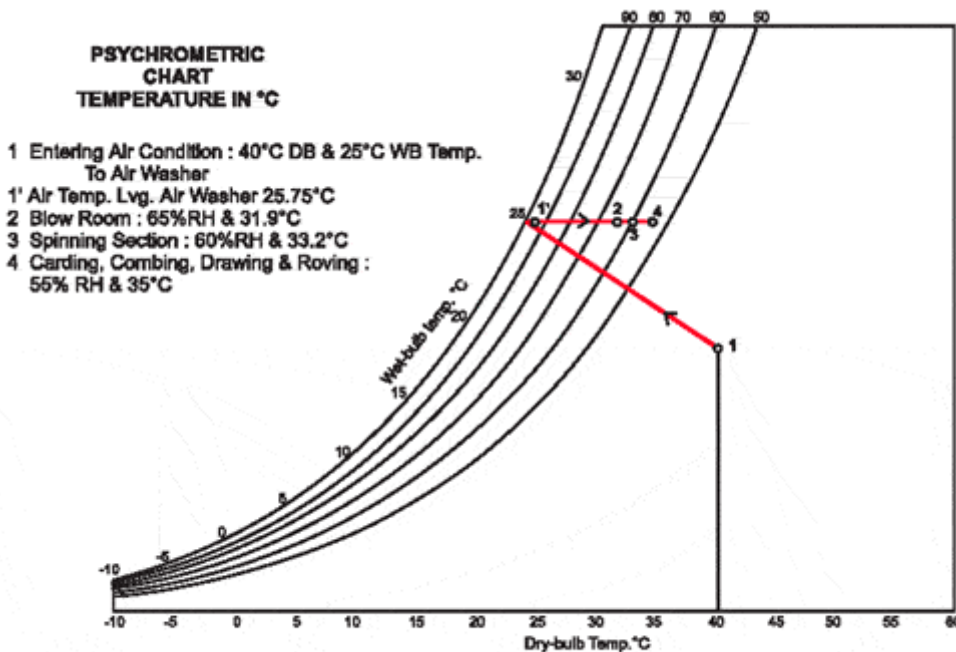


Figure 2 : Mill humidification process.

Department	Design Inside Relative Humidity	Corresponding Inside Dry Bulb Temperature
Blow Room	65%	31.9°C
Carding & Combing Drawing & Roving	55%	35.0°C
Ring-Spinning	60%	33.2°C

Air Washers

Spray air washers using spray water as the medium for adiabatic cooling of air (by direct evaporation of water into the air stream thereby reducing the air's dry-bulb temperature

and raising its humidity) are extensively used in humidification systems for textile mills, due to the following advantages.

- Significant saving in initial capital cost and energy cost with evaporative cooling systems, compared to air-conditioning systems.
- Reduced power demand with reduction in electrical maximum demand charges
- Improved air quality due to air cleaning properties of spray water.
- Flexibility to use chilled water in air washer instead of normal temperature water, when outside air is exceptionally hot and humid Some mills which deploy chillers for spinning and weaving areas use chilled water spray occasionally, mainly in the hot and humid season when evaporative cooling is not feasible.
- Humidification system deploying water as cooling medium is environment friendly.

Air Washer Components & Construction

Spray air washers generally used in humidification plants, consist of a chamber containing multiple banks of spray headers with spray nozzles, a tank for collecting spray water as it falls and an 'eliminator section' with PVC blades having 3 or 4 bends for removing droplets of water from the air which is humidified after passing through the curtain of spray water, before discharge to the air ducts for distribution to the humidified areas.

Air velocity, water spray density, spray pressure and other design criteria are optimized by each manufacturer, depending on the air-washer dimensions and spray header /nozzle sizes and configuration and eliminator design which they have developed for different applications. Earlier designs of air washers were based on low air velocity, upto 3m/s (600 fpm). Some manufacturers have now developed high velocity air washers operating at 6m/s (1200 fpm) and even upto 9m/s (1800 fpm) air velocities which make the unit compact and facilitate shipment in pre-fabricated and assembled condition. However, high velocity air-washer designs require special eliminator design and construction and due to the additional pressure drop, the supply fans are to be selected at a higher static pressure

Single spray bank air washer is not selected for mill humidification due to its lower saturation efficiency.

Double bank opposed spray type with G I header and stand pipe assembly and gun-metal / plastic spray nozzles are often used in air washers for mill humidification, since with this configuration it is possible to achieve 95% saturation efficiency with spray density of 3 gpm/ft² and air velocity not exceeding 3m/s. The degree of saturation depends on the contact efficiency between air and water. A low velocity air flow is more conducive to a

higher saturation efficiency. However, manufacturers of high velocity air washers have now optimized their system for obtaining high saturation efficiency upto 95% with higher spray density.

Resistance to air flow through the air washer varies with the type and number of inlet baffles, (for uniform air-distribution through spray chamber), eliminator design, number of spray banks, air velocity, other components such as heating coil if any, dampers etc. and the total pressure drop can vary between 15 mm to 30 mm w.g depending on the overall size, air velocity, spray header and eliminator design.

Pre-fabricated air washer units with sheet metal casing and F.R.P lined MS tank and other internal components in assembled condition are available in small and medium capacities upto 170,000 m³/hr. (100,000 cfm)

For large capacity air washers, casing may be constructed in masonry and water tank in R.C.C and components including spray system, eliminators, spray pumps, supply and return fans, dampers, rotary return air filters and water filters are assembled at site.

Sr. No.	Department	Volume of space (M ³)	Machinery operating kW load	Inside Design Relative humidity (%)	Conditions Inside DBT (at summer outside condition specified) (°C)	Estimated Air supply flow rate cmh	Air changes per hour
1.	Blow Room	3150	96	65%	31.9	64,000	20
2.	Carding, combing, draw frames and roving (preparatory areas)	11,300	422	55%	45.0	1,67,000	15
3.	Ring Frame (Spinning)	13,200	1050	60%	33.2	4,70,000	36

Figure 3 : Humidification design parameters for a typical spinning mill in western Maharashtra with summer outside design conditions of 40°C DBT & 25°C WBT

Calculation of Humidification Heat Load & Supply Air Quantity

The room sensible heat load calculations are worked out as the sum-total of :

- Heat dissipation from the machines' operating kW load in various departments.
- Lighting load
- Solar heat gain through insulated roof
- Occupancy load
- Heat gain from supply air fan motors

Temperature of humidified air leaving the air washer based on summer outside design dry bulb and wet bulb temperatures and design saturation efficiency is calculated as follows and plotted on the psychrometric chart **Figure 2**.

$$\text{Leaving Air Temperature from air-washer} = \text{Ent. Air DBT} - (\text{Ent. Air DBT} - \text{Ent. Air WBT}) \times \% \text{ sat. efficiency}$$

The line of supply air temperature rise in the department due to heat gains is plotted horizontally, starting from the point of "leaving air temperature condition" after humidification in air washer, till it reaches the design relative humidity line for the corresponding department.

The required supply air quantity is calculated as follows:

$$\text{Supply Air Quantity in cfm} = \frac{\text{Room Sensible Heat BTU / hr}}{1.08 \times \text{temp. rise of humidified air in } ^\circ\text{F}}$$

In a typical spinning mill humidification application in western Maharashtra, calculated supply air quantities for various humidified areas provide following air changes:

	Air changes/hr.
Blow Room	20
Carding, combing draw frames & roving	15
Ring-Spinning	36

Type of Fans Used

High efficiency axial flow fans, with aluminum impellers, adjustable pitch aluminum blades with direct drive totally enclosed IP-55 motors are usually selected to deliver the design supply air quantity against the required static pressure, after considering pressure drop in fresh air damper, air washer internals, washer-dampers, supply air ducting, and

supply air diffusers with volume control dampers. Design static pressure for supply air fan selection can vary from 40 mm to 55 mm w.g depending on the air washer length, spray headers and eliminators design, other internal components including heating coils, if any, design air velocity etc.

Return air fans are sized to recirculate upto 95% of design supply air quantity for each department, by considering the design static pressure required to overcome pressure drop in the return air floor grilles, masonry return air trench, 'rotary drum type return air filters', return air dampers etc. Since the pressure drop in rotary drum filters when dirty can be as high as 30 mm w.g, the return air fan selection in mill humidification applications should account for upto 25 mm w.g. pressure drop in air filters and the return air fan selection and motor kW should cater to the required return air flow rate against a total static pressure of 50 to 55 mm w.g. after considering pressure drop in the floor grilles and return air trench.

Air Filter Construction & Cleaning System

Automatic rotary air filters have a rotating type drum, made of perforated steel sheet and fitted with suitable filter media to arrest fluff and are fitted with drive mechanism and geared motor and necessary suction nozzles connected to a flexible suction hose for automatic cleaning and removal of the dust and fluff with centrifugal type suction fan (direct driven by TEFC / IP- 55 motor) into a waste collection unit.

Automatic cleaning is necessary, since the extent of generation of dust and fibre-fly varies and pressure drop in the filter is to be kept within the design limit so as to prevent reduction of outgoing air flow and also save energy consumed by the blower. Any reduction in outgoing return air flow is to be prevented to avoid build up of fluff and fibre fly since these will contaminate and spoil the yarn produced.

Waste Collection & Handling Systems

Modern blow room (opening and picking) equipment, cards and draw frames, combers, open-end spinning and some new-design looms have suction orifices at various points of fluff generation in order to suck back the air containing waste fibres, which is then taken through duct work/pipes and rotary type pre-filters by a high-static blower unit of a central suction system.

The waste fibres are sucked off from the pre-filter unit and separated by a fibre compactor unit into bales. The pre-filtered air still containing micro-dust is again filtered by rotary fine filters and taken into the under-floor return air stream by axial flow return air

fans back into the humidification plant room for exhaust to atmosphere or to be recycled to recover part of the heat.

Supply Air Distribution

Textile plants are generally served by uniform air distribution through sheet-metal ducts run above the false ceiling in respective departments and taking care in the design to direct supply air through suitably positioned outlets to motor-alleys and other points of concentrated heat loads.

In the 'weave direct' (loomsphere) system of humidification for a weaving shed, a separate air washer unit with independent supply fan and ducting system with branch ducts coming down to a level of approximately 1.2 metres above the warp sheet of respective looms for directing the humidified air to the warp sheets are used to attain the desired high relative humidity condition of 78% to 80% at the warp sheet level of the looms. A separate air washer unit with separate supply fan and separate supply air ducting running above the false ceiling and ceiling diffusers at the false ceiling level are adopted to maintain around 65% R.H condition in the room itself.

Water Quality

Quality of water to be recirculated and sprayed in the air-washer should be within the following limits:

PH value : 7.5 to 8.5

Total hardness: preferably above 100 mg/litre and within 250 mg/litre.

De-mineralized water used in boilers should not be used in air washers as this may lead to corrosion. Moderate hardness helps to build a thin protective coating which reduces harmful effects of chlorides in coater.

Because of evaporation of water drops, minerals tend to concentrate during re-circulation. Hence it is necessary to bleed some water from the air washer tank and also do periodic cleaning to prevent growth of algae.

Humidification Design Features for Energy- Saving

1. Loomsphere (Weave-Direct)

The system of loom humidification, described above provides high relative humidity required at warp sheet level and also results in overall reduction of total

humidified supply air quantity by almost 25%, thereby achieving significant saving in energy cost.

2. Return Air System

a) Return air trenches should be designed with minimum corners and bends and should be given a smooth finish to reduce air-resistance.

b) Rotary return air drum filters with effective suction fan for continuous fluff removal will help to keep the return air filters clean and reduce air resistance, thereby reducing power consumption of return air fan motor.

3. Underdeck Insulation

Generally, industrial roofing is of asbestos cement sheets or metal sheets (GI / Aluminum) and underdeck insulation with minimum 50 mm thick resin bonded glasswool of 32 kg/m³ density is necessary to reduce the heat gain through the roof and minimize the attic temperature rise within the false ceiling.

4. Drive motors for textile machinery

Since the connected textile machinery loads are very high, only high efficiency drive-motors should be selected to reduce the heat gain and the heat load, thereby reducing the supply air quantities to the departments being humidified thus minimizing supply fan motors' power consumption.

5. Use of PVC air inlet louvers and eliminators

With PVC blades and moderate air velocity (not exceeding 600 fpm for low velocity air washer system and not exceeding 1200 fpm for high velocity air washer system) are desirable to reduce the air resistance in the air washer with consequent reduction in design static pressure for supply air fan selection so as to reduce fan motor power consumption.

6. **Use of variable speed drive** (invertor control) on air washer water circulation-cum-spray pumps, helps to achieve power saving on part load operations. However, variable speed drive for fan motors is generally not adopted since any reduction in air flow can slow down the removal of fluff and other waste materials and contaminate the department causing quality deterioration of the yarns / fabrics inside.

7. **Higher saturation efficiency** of air washer Saturation efficiency is defined as

the ratio :
$$\frac{\text{Entering Air DB} - \text{Leaving air DB}}{\text{Entering Air DB} - \text{Entering Air WB}}$$

Improving the saturation efficiency reduces the temperature of air leaving the air washer thereby increasing the delta 'T' (temperature rise of saturated air due to heat

pick up in the department) for a specific heat load and relative humidity condition in the department with consequent reduction in required supply air quantity and fan motor power consumption.

Good design and maintenance of air filters to minimize fluff carry over into the air washer unit, proper spray density in air washers and proper sizing and cleanliness of spray nozzles to improve water distribution also helps improve saturation efficiency of an air washer for reducing supply air flow-rate and bring down energy cost.

8. **Use of digital controls in conjunction with electronic temperature & humidity sensors** in humidification plants for getting feedback of temperature and relative humidity conditions in each department of the mill and processing of such information by digital controller for automatic control of the position of outside air exhaust air, return air and by-pass air dampers' positions will maintain stable inside condition in the departments with added benefit of power saving at part load conditions.

Conclusions

Energy efficient and fully automated humidification systems for textile mills will immensely help the Indian textile industry to meet the challenge presented by the end of the quota regime and the prospects of doubling textile exports from \$12.5 billion currently to \$25 billion by 2008.

Exports aside, textile mills are ramping up capacity to cater to the growing \$21 billion domestic market which is seeing a large growth in demand with higher disposable incomes in the hands of the middle class who will now have access to almost 500 malls slated to come up in the next two years all over the country.