which is released by a thread break and automatically stops the loom. Another automatic mechanism will insert a new quill in the shuttle as the previous one is emptied, without stopping the loom. Still others are actuated by filling breaks, improper shuttle boxing, and the like. The loom stays down *until restarted manually. Each cycle may leave a stop-mark* sufficient to cause an imperfection that may not become apparent until the fabric is dyed.

Beyond this basic machine and pattern, are many complex variations in harness and shuttle control which give intricate and novel weaving effects. The most complex is the jacquard with which individual warp threads may be separately controlled. Other variations appear in looms for such products as narrow fabrics, carpets, pile fabrics, and in the Sulzer weaving machine in which a special filling carrier replaces the conventional shuttle.

High humidity increases the abrasion resistance of the warp, and many weave rooms require 80 to 85 percent and even higher for cotton and up to 70 percent for man-made fibers. More recently, however, improved sizes have slightly reduced the higher values. Many looms can be run much faster when humidity is precisely controlled; and still faster when temperature is controlled.

In the weave room, the distribution of power is quite uniform with an average concentration somewhat lower than in spinning. The rough treatment of fibers causes the liberation of many minute particles of both fiber and size, thereby, creating considerable amounts of airborne dust. Air changes will average from 4 to 8 per hr due to high humidity. It is frequently advisable, particularly with man-made fibers, to make special provisions for maintaining conditions overnight and through week-ends.

KNITTING

Most knitting processes afford much greater fabric elasticity than weaving, and are, therefore, used extensively in the manufacture of form fitting articles and fabrics. Typical of these are the seamless articles, made on circular machines, such as undershirts, socks, seamless hosiery, and those knitted flat such as full fashioned hosiery, tricot, milanese, or warp fabrics.

Regardless of the type of machine, the basic process is one of generating fabric by forming millions of interlocking loops. In its simplest form, a single end is fed to needles which are actuated in sequence. In more complex constructions, hundreds of ends may be fed to groups of elements which function more or less in parallel. Variations in type of machine, pattern of loops and yarn impart different fabric characteristics.

Knitting yarns may be either single or ply and must be of uniform high quality and free from neps or knots. In most instances, they are either double-carded or combed, and are given a special soft *knitting twist* to enhance yarn and fabric elasticity. Knitting yarns, particularly the multi-filament, are usually treated with special sizes to keep broken filaments from stripping back and to provide lubrication.

The generation of loops of identical size and shape is the ultimate in knitting perfection and, perfection depends largely upon uniformity of yarn tension as well as the precision of machine adjustments. The necessity for a more precise control of tension increases with the fineness of product. It reaches a maximum in the finer gages of full fashioned hosiery and the finer warp fabrics in which a 2 F deg change in temperature is a limit of tolerance and a 10 percent change in humidity may add or subtract 3 in. in the length of a stocking. A dry bulb of about 76 F with humidity ranging from 45 to 65 percent according to the fiber, is desirable. Fine gage full fashion machines are critically affected by drafts.

FINISHING

Finishing is the final readying of a mill product for its particular market. Its scope is very broad and variegated, ranging from cleaning to imparting special characteristics.

The individual operations, as well as the number involved, vary considerably with type of fiber, yarn or fabric, and end product usage, and are usually done in plants separate from the mill. Included might be: (1) inspection for the detection and repair of minor defects; (2) singeing, to burn away fuzz and produce a smoother surface; (3) napping, to increase fuzziness; (4) shearing pile fabrics which are frequently woven face to face; (5) soaping and washing, to remove dirt, grease spots and size; (6) bleaching, to remove additional size and to improve whiteness; (7) mercerizing, to produce greater luster, strength, and dye affinity; (8) drying, by heated rolls or chambers or with centers, to straighten and control the width of cloth; (9) printing, to add color or pattern; (10) dyeing; (11) *Sanforizing;* (12) calendering; and (13) embossing.

Inspection is the only finishing operation to which air conditioning is regularly applied, although most of the others require ventilation. Those which employ wet processes usually keep their solutions at high temperature and require a special type of ventilation to prevent destructive condensation and fog. In all, where the release of sensible, latent, or radiant heat is great, spot cooling is indicated.

FACTORS WHICH DETERMINE OPTIMUM CONDITIONS

Air conditioning functions as a production tool by its beneficial influence on the three basic elements of textile production: (1) the workers, (2) the materials from which products are made, and (3) the machines with which they multiply their efforts. Since all react in various ways and magnitudes to temperatures, to humidity, and to changes in either or both, a separate consideration of each is the best approach *to the selection of design conditions and type of system.*

Workers

The consideration with respect to workers is enabling them to do more work and better work with less fatigue and loss of acuity, by freeing them from the physiological and psychological reactions which are caused by heat stress.

The value of increases in human efficiency depends upon the amount of labor in overall cost and upon the influence which the individual can apply to materials and machines. In the old spinning wheel, for example, this influence was just about 100 percent, but in modern production it varies with machine and process.

Although a sparse population is typical of most departments, the labor in an average cotton carded yarn may be approximately 25 percent of its total cost while for various fabrics it may be from 15 to 34 percent. It is important to note that the cost of material greatly influences distribution of the dollar. In addition, it is vital to note that these values are broad averages and that labor cost per unit of product has actually been found to vary plus or minus 19 percent in mills making the same product. Much of this variation may be accounted for by differences in machinery and mill practice.

In the selection of internal conditions, conventional comfort practice is not always permissable. The relative humidity is usually determined by type of fiber or blend and step-of-process. The minimum dry-bulb temperature is usually 80 F. Lower dry-bulb temperatures are acceptable in knitting but, otherwise, most mills like to operate at 80 F in mid-winter. Hence, the lowest effective temperatures are usually higher than those demanded in the comfort field.

Materials

The considerations with respect to materials are making them more manageable and bringing out the best of those latent properties which are affected by moisture content and temperature.

The greater part of manageability is derived from constancy. The best of physical properties are such as strength, flexibility, cohesiveness, elasticity, generation of static, resistance to abrasion, and dimensional stability. The constancy of most of these properties is a matter of great importance because changes alter fiber behavior and the reaction of yarn to tensioning devices, thread guides, etc.—and is greatly improved by a precise control of temperature and humidity.

All textile fibers are affected by humidity and many by temperature. Nearly all fibers are hygroscopic, as are the sizes, antistatics, gums, or other materials with which some must be transiently impregnated. Both glass and metallic yarns adsorb a surface film of water and, hence, are affected by changes in humidity. The ideal control is a constant regain in the fiber or a surface film of uniform density.

Regain depends primarily on relative humidity and varies in a direct relationship. It is inversely affected by temperature. A rise in dry-bulb temperature will depress regain when relative humidity is kept constant but by a usually insignificant amount. Several hours are required for a well exposed strand of yarn to approach equilibrium. Large packages change very slowly, and, if regain is lower, the unwinding rate may greatly exceed the rate of recovery.

The level at which humidity should be controlled and the variation in temperature that may be tolerated is determined solely by the combination of fiber, process, and machine. Precise recommendations are normally impractical due to the multiplicity of fibers and blends as well as subtle differences in mill practice and machinery. Hence, the design conditions should be worked out in consultation with mill management to whom the technical services and pilot plant experience of the fiber manufacturer will be available.

Machines

The principal consideration with respect to machines is minimizing the creeping loss of adjustment that may be caused by hour-to-hour changes in temperature. Some parts of some machines, such as shuttle boxes, tapes, belts, and brakes, are frequently made of hygroscopic materials, and changes in relative humidity will cause dimensional and frictional changes which will disturb adjustment or, for all practical purposes, destroy it completely.

The metallic parts of machines vary in cross-sectional area, or, more precisely, in the ratio of heat transfer surface to weight of heat absorbing metal. Hence, those of light cross-section will follow ambient changes in dry-bulb temperature more rapidly than the heavier parts. The result is a dimensional distortion which will alter the adjustments of some machines beyond the limits of tolerance. Factors of both speed and precision are involved in many instances. The need for stability is related to the precision and complexity of the machine and the fineness of the product.

Since these creeping losses of adjustment are caused only by fluctuations, the levels at which temperature and humidity are controlled are of secondary importance.

AIR CONDITIONING SYSTEMS

Systems applied to textile conditioning fall broadly into two divisions: (1) those absorbing heat and adding moisture by evaporative cooling alone, and (2) those employing evaporative cooling in winter but supplemented by refrigeration in summer. Both are capable of producing year-round control of relative humidity, but only refrigerated systems are capable of maintaining constant room temperature and preventing a temperature rise during summer.

Since, for a given outdoor wet-bulb temperature, room temperature is determined primarily by the relative humidity to be maintained, use of refrigerated systems is largely dictated by humidity level desired. For instance, cotton Weave Rooms operating at the 85 percent level seldom employ refrigeration since temperatures of 87 F and below may be obtained by the use of less expensive evaporative cooling. Processes requiring lower humidities, such as modern spinning which operates best at 40 to 50 percent, find refrigeration necessary to prevent excessive and almost unbearable temperatures. Between these humidity extremes, system selection varies greatly, but with a general division at 60 to 65 percent. Those who do elect to install evaporative cooling for lower humidities, usually select systems to which refrigeration may be added later.

Mill conditioning may be divided further into several categories, depending upon the basic method used. One method depends upon the evaporation of free water in the conditioned space. As the water particles evaporate, sensible heat required for evaporation lowers the space temperature, while the conversion of sensible to latent heat raises the humidity. Another method introduces un-humidified air in combination with direct evaporation of water in the room. A third method uses evaporatively-cooled and nearly saturated air to add humidity and absorb heat directly by air temperature rise. The *fourth method* uses a combination of these three principles.

Atomizer System

Atomizer systems are, in effect, all-water systems which atomize water in the upper areas of the space, breaking it up so finely that it evaporates before coming in contact with building or machinery. Most of them employ compressed air, but some use mechanical means. Heating is done separately, usually with unit heaters.

Since there must be some means of overall heat removal, the resultant mill dry-bulb temperature depends upon three factors: (1) the amount of sensible heat which is converted into latent, (2) the amount of infiltration which may be caused by open windows and gravity ventilators, and (3) by outward transmission during all or part of the cooling season. The control of mill relative humidity functions by stopping and starting the atomizers or by modulating their output. The effect is to raise room dew point and maintain it in proper dew-point depression relationships with concurrent dry-bulb temperatures. Since no significant amount of air is dynamically introduced, both mill dry-bulb temperature and the fluctutions therein are the greatest with this system, and distribution depends primarily on thermal currents. Its cost is substantially lower than that of other systems, but there is no means by which refrigeration may be added.

Air Changer System

This arrangement (Fig. 3), sometimes called the dry-duct system, combines atomizers with forced ventilation and air circulation. It differs from atomizer systems in that it removes mill heat by a positive and controlled introduction of outdoor air. Fan-coil unitary equipment, with or without ducts, is usually applied. The atomizers are usually placed above the outlets thereby improving the admixture of moisture and air. Each unit is equipped with outdoor and return air dampers which may be automatically controlled, together with a steam reheat coil usually located at the return air inlet.