TECHNICAL NOTE NUMBER 217

FOREST PRODUCTS LABORATORY
MADISON, WISCONSIN

UNITED STATES FOREST SERVICE
REVISED FEBRUARY 1938

THE MANUFACTURE OF RAYON

Rayon, formerly called artificial silk, is a soft, pliable textile fiber produced from some form of plant cellulose, such as cotton or wood pulp. In the manufacturing process the cellulose is dissolved to a viscous solution and forced through minute apertures corresponding to the spinnerets of the silkworm. The fine continuous threads or filaments coming through these apertures are coagulated either in a liquid bath or by the evaporation of the solvent, and several of them formed simultaneously are twisted into yarn.

A smaller but rapidly increasing amount of rayon yarn is produced by cutting the filaments into definite lengths before they are twisted and then spinning them into yarn in a manner similar to that in which cotton, wool, or spun silk yarns are made. The cut filaments are referred to as rayon staple fiber and the yarn thus produced is known as spun rayon.

The name "artificial silk" is somewhat misleading. Rayon was formerly made with a bright silky luster, but is now available with varying degrees of luster from bright to chalky. Chemically it is quite unrelated to natural silk, which consists of a core of so-called fibroin covered with a shell of sericin or silk albumin. Both of these compounds contain nitrogen. Rayon, on the other hand, is composed simply of fine threads of cellulose or a cellulose ester. Its peculiar physical appearance is due to the solution processes which alter the normal appearance of the cellulose by what is termed "hydration." It contains no nitrogen or, at most, only traces of this element. A simple and fairly reliable

test to distinguish rayon from silk can be made by burning a piece of the yarn. Rayon burns without odor and, except for acetate rayon, without an ash residue. The acetate rayon leaves a small bead of ash on the end of an unburnt thread. Silk gives off a pungent odor on burning and leaves a small bead of ash on the thread.

The term "rayon" was coined to distinguish "cellulose silks" from the natural product and to eliminate the confusion which existed regarding the two materials. This name has been endorsed by both manufacturers and consumers of the product in the United States, Canada, and England, and has come into common usage. It succeeds a host of names among which are "glos," vegetable silk, glanzstoff, fibersilk, collodion silk, cuprammonium, etc.

Four types of rayon have been manufactured on a commercial scale. The methods used differ chiefly in the chemical solvents used. The products are differentiated as nitrocellulose or Chardonnet, cuprammonium, viscose, and acetate rayons. The nitrocellulose process is the oldest; the viscose process is the most important commercially. All these processes except the first, which has been abandoned, are used in the United States. Other processes in which the yarn filaments are made from cellulose ethers and esters other than the acetate are being investigated and offer promise of commercial development.

In the nitrocellulose process cotton cellulose is converted to a nitrocellulose by treatment with nitric and sulphuric acids. The nitrocellulose is dissolved in an alcohol-ether mixture, and threads are formed by forcing the solution through the spinnerets, after which they are coagulated almost instantly by the evaporation of the ether and alcohol. The product undergoes various refinements including bleaching and denitration with an alkaline sulphide to render the

yarn less inflammable. It has been variously known as Chardonnet, Lehner, tubize, collodion, pyroxylin, or nitrocellulose silk.

The cuprammonium or Despaissis process also starts with cotton using ammoniacal copper oxide (Schweitzer's reagent) as a solvent. The solution is forced through capillary tubes first into water and then into dilute sulphuric acid, the filaments being stretched as they are solidified. They are then thoroughly washed and dried. Most of the copper and ammonia are recovered. Rayon made by this method has been known as cuprammonium, Despaissis, Pauly, or glanzstoff silk.

In the viscose process either cotton linters or wood pulp or a mixture of the two is first steeped in caustic soda to form alkali cellulose. The alkali cellulose is then pressed, shredded, and treated with carbon disulphide to form cellulose xanthate. The xanthate is dissolved in a dilute caustic soda solution to make the viscose spinning solution. The viscose is forced through the spinneret and the filaments coagulated in a bath containing sulphuric acid, sodium sulphate, zinc sulphate, and sometimes glucose. The yarn is then washed, dried, and treated with alkaline sulphide solutions to remove residual sulphur or sulphur compounds, and bleached.

Acetate rayon is the latest type to be produced on a commercial scale. Unlike the rayon produced by the other processes, which is pure cellulose, acetate rayon is an ester of cellulose, the cellulose being chemically combined with acetic acid.

Cellulose acetate is prepared by treating cotton or wood pulp with acetic acid and acetic anhydride in the presence of a suitable catalyst and precipitating the acetate in water. The cellulose acetate is then dissolved in acetone to make the spinning solution.

The filaments, after passing through the fine holes of the spinneret, are coagulated by evaporation of the acetone in a current of warm air.

The viscose process, by which about three-fourths of the domestic output is produced, operated for many years exclusively on wood pulp. The other processes used only cotton. Now, either cotton or wood pulp or mixtures of the two are used in the viscose process (it is the general practice to use mixtures) and interest is being shown in the use of wood pulp in the other processes. The wood pulp is principally high-grade bleached sulphite made from spruce or western hemlock. Bleached sulphite pulp from other conifers and also from hardwoods has been reported satisfactory and probably a pure pulp from almost any species could be used. Although it has been difficult to obtain pulp of the desired quality by the sulphate process considerable progress has been made in this direction and sulphate pulps reported to be satisfactory for rayon manufacture have been produced.

Whether the raw material is cotton linters or wood pulp, it must be free from vegetable greases, coloring matters, and similar impurities, and in all processes a preliminary alkali cleansing treatment is necessary. One requirement seems to be the use of the stable or alpha-cellulose. Cotton normally is practically pure alpha-cellulose, but in wood pulp other lower or more unstable forms are present. The alkali treatment eliminates a large portion of the latter and renders the pulp suitable for use.

The manufacture of rayon is one of the most rapidly developing cellulose industries. Established during the present century it has attained a position of outstanding importance. By way of comparison the production of raw or reeled silk in the silk-crop year of 1923-24 was approximately 110,000,000 pounds as

against an estimated world production of 103,000,000 pounds of rayon in 1923. In 1927 the world rayon production had increased to 298,000,000 pounds, and in 1934 to 824,000,000 pounds of rayon yarn and staple fiber. In 1936 the estimated world production of rayon yarn and staple fiber was 1,325,000,000 pounds, of which 22 percent was produced in the United States.

Successful operation of a mill producing rayon involves a large capitalization and a high degree of technical skill. A factory must be well equipped and in good location with respect to markets. It must have a constant supply of pure, clear, soft water.

The capital requirements of a rayon manufacturing plant may vary widely with the location and other factors. Avram, in his book "The Rayon Industry" estimates that a plant with a daily capacity of three tons will cost about $3,000,000 and that $500,000 additional should be provided for working capital. A daily capacity of one ton is considered the minimum scale of economical operation and in this case the investment necessary would be about $1,600,000, including working capital. The production costs are about equally divided among labor, raw material, and depreciation and overhead, but labor may sometimes account for as much as 50 percent of the total cost. Since depreciation and overhead represent a large portion of the cost it is highly desirable that the operation of a rayon plant be maintained as close to full capacity as possible.