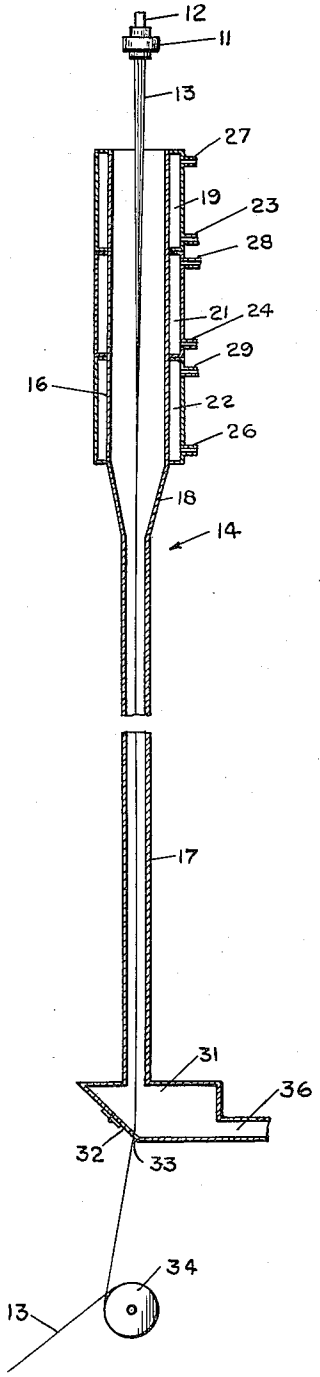
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PROCESS FOR SPINNING

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## PROCESS FOR SPINNING

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This invention relates to a process for spinning, and relates more particularly to a process for spinning in which a high-velocity stream of evaporative medium is maintained in the spinning cabinet in the direction of travel of the filaments.

In the so-called "dry-spinning" process for the production of artificial filaments, a solution or dope of filament-forming material in a volatile solvent is pumped or otherwise forced through a spinning jet, containing one or a plurality of spinning orifices, into a spinning cabinet or metier. As the filaments pass through the spinning cabinet, the solvent is evaporated therefrom by means of a stream of any suitable evaporative medium such as air. The solvent-free filaments are then drawn from the spinning cabinet and may be lubricated and have a twist imparted thereto before they are taken up in package form.

To obtain satisfactory results, it is important, in carrying out this process to maintain the tension on the filaments as they leave the spinning cabinet between about 0.02 and 0.2 gram per denier. Tensions lower than about 0.02 gram per denier are undesirable since, when filament yarns are being produced, they result in a loopy yarn, namely a yarn in which some of the filaments are longer than others and stand away from the body of the yarn in loops. On the other hand, tensions above about 0.2 gram per denier are equally undesirable since the physical properties of the filaments are unfavorably affected by being subjected to excessive stresses during spinning. These stresses, acting on the filaments before the solvent has been completely evaporated therefrom, tend to embrittle the filaments and reduce their percentage elongation under stress. If the tension on the filaments rises much above about 0.2 gram per denier, it may even cause filament breaks interrupting the continuity of spinning.

As a result of these limitations upon the tensions to which the filaments may be subjected, it has hitherto been customary to maintain the speed of the filaments during the spinning operation between about 300 and 600 meters per minute, and in no case to permit the speed to exceed about 800 meters per minute. If an attempt is made to employ higher spinning speeds, the tension on the filaments rises rapidly above about 0.2 gram per denier producing defective filaments and causing filament breaks. This limitation on the maximum permissible spinning speed seriously curtails the productive capacity of conventional spinning processes and apparatus.

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It is an important object of this invention to provide a process for spinning, which will be free from the foregoing and other disadvantages of the prior art processes and apparatus, and which will be especially efficient in operation and simple in construction.

A further object of this invention is the provision of a process for spinning in which a high velocity stream of evaporative medium is maintained in the spinning cabinet in the direction of travel of the filaments.

Another object of this invention is the provision of a process for spinning in which such high spinning speeds are employed as to produce filament tensions above about 0.2 gram per denier, but which filament tensions are reduced to below about 0.2 gram per denier by means of a high velocity stream of evaporative medium in the spinning cabinet in the direction of travel of the filaments.

A still further object of this invention is to provide a process for spinning in which the spinning speed is above about 800 meters per minute, and the filament tension is maintained below about 0.2 gram per denier by means of a high velocity stream of evaporative medium in the spinning cabinet in the direction of travel of the filaments.

Yet another object of this invention is the provision of a process for spinning in which the spinning speed is above about 800 meters per minute, and a stream of evaporative medium is passed through the spinning cabinet in the direction of travel of the filaments at a velocity such that the difference in velocity between the filaments and the stream of evaporative medium does not exceed about 600 meters per minute.

A further object of this invention is to provide a process for spinning in which a stream of evaporative medium is passed through the spinning cabinet in the direction of travel of the filaments, and said stream of evaporative medium has a velocity ranging from about 35 to 95% of the velocity of said filaments.

Other objects of this invention, together with certain details of construction and combinations of parts, will be apparent from the following detailed description and claims.

We have now discovered that the excessive tension on the filaments at high spinning speeds is due, at least in part, to air drag, and that the tension may be reduced to a proper value by maintaining a high velocity stream of evaporative medium in the spinning cabinet in the direction of travel of the filaments. This relatively

simple expedient permits the maximum spinning speed to be more than doubled, reaching 1400, and even more, meters per minute without an excessive increase in the tension on the fialments. Since the productive capacity of a spinning cabinet varies directly with the spinning speed, the increase in the maximum spinning speed results in a comparable increase in the capacity of the spinning cabinet.

The discovery that the excessive tension on the filaments at high spinning speeds is due, at least in part, to air drag is considered surprising since the surface area of the filaments upon which the air acts is relatively small. It appears, however, that the cumulative effect of the air drag over the entire length of the filaments raises the filament tension to excessive values at high spinning speeds.

While it has previously been proposed to have the air flow through the spinning cabinet in the direction of travel of the filaments, the air velocities hitherto employed have been so low as to have substantially no effect on the filament tension. In fact, the air velocities have been sufficiently low as to permit comparable results to be obtained with the air flowing either in the direction of travel of the filaments or in a direction contra thereto. Similarly, proposals have been made to have an air nozzle positioned in the spinning cabinet to act on the filaments to draw them down, but the localized action of an air nozzle has been found not to appreciably affect the maximum spinning speed or the percentage elongation of the filaments produced. In addition, the spinning speed of the filaments to which these expedients have been applied has been so low that air drag was of no particular importance in determining filament tension.

We have found that at high spinning speeds a critical relationship must be maintained between the spinning speed and the velocity of the air stream through the spinning cabinet if the production of defective filaments is to be avoided. The air velocity will depend on the spinning speed, but should, in all cases, be sufficient to bring the filament tension down from whatever value above about 0.2 gram per denier it would have in the absence of the air stream to a value between about 0.02 and 0.2 gram per denier. This may be accomplished by employing air velocities not lower than about 35% of the spinning speed nor higher than about 95% of the spinning speed. Lower air velocities will permit the filament tension to reach excessive values causing defective filaments and filament breaks, whereas higher air velocities will reduce the filament tension to a point so low as to result in loopy yarns. In general, the difference in velocity between the filaments and the air stream should not exceed about 600 meters per minute, so that the air velocities should range from about 280 to 750 meters per minute at a spinning speed of about 800 meters per minute, and should increase with an increase in the spinning speed, so that at a spinning speed of about 1400 meters per minute, the air velocities should be between about 800 and 1300 meters per minute.

Any one of a number of expedients may be employed to obtain the desired air velocity in the spinning cabinet. For example, air under pressure may be admitted into the spinning cabinet, or the air may be exhausted from the spinning cabinet. Although the desired air velocities will be obtained by employing either of these alternatives, the use of air under pressure is somewhat less desirable since it requires that the static pressure within the spinning cabinet be above atmospheric. When such an excess of pressure exists within the spinning cabinet there is a tendency for the air to escape into the atmosphere carrying with it the solvent vapors. If, however, the flow of air is obtained by exhausting air from the spinning cabinet, the static pressure in said cabinet will be below atmospheric, and there will be no tendency for an escape of vapor laden air.

To obtain the desired reduction in the filament tension, it is essential that the air stream act on the filaments during substantially their entire travel through the spinning cabinet. However, in certain cases, the high velocity air stream may be excessively turbulent when it is formed, and if said turbulent air stream is permitted to act on a bundle of filaments directly as they leave the spinning jet and while they still contain the major portion of the solvent it will cause the filaments to coalesce with each other. We have found that such coalescence of the filaments may be avoided by increasing the air velocity gradually in the vicinity of the spinning jet so that the air flows past the newly-formed filaments smoothly and without turbulence. This gradual increase in air velocity may be accomplished readily by increasing the cross-sectional area of the spinning cabinet in the vicinity of the spinning jet. Provision may also be made for the filaments leaving the spinning jet to pass through a zone in which the air is relatively quiescent to permit an initial evaporation of solvent from the filaments to take place before they enter the high velocity air stream.

The solvent-vapor laden air leaving the spinning cabinet is passed to a solvent recovery system in which the solvent is recovered for further use. To avoid the necessity of handling excessively large volumes of air in the solvent recovery system, it is desirable to maintain the concentration of solvent vapors in the air leaving the spinning cabinet above about 1.5%. Since this limits the volume of air which may be passed through the spinning cabinet to evaporate a given quantity of solvent from the filaments, it is necessary to adjust the cross-sectional area of the spinning cabinet to obtain a sufficiently high air velocity without exceeding this upper limit on the air volume. The specific cross-sectional area of the spining cabinet may be readily calculated once the air velocity, the desired concentration of solvent vapors, and the quantity of solvent to be evaporated in a given time are known.

The spinning cabinets of this invention may be constructed to have a square, rectangular, circular, elliptical or other cross-section. However, since the spinning cabinets must be of limited cross-sectional area to maintain a high concentration of solvent vapors in the effluent air, it is preferred to employ cabinets having a circular cross-section which will provide the highest clearance between the filament and the walls of the cabinets for any given cross-sectional area. Spinning cabinets having a circular cross-section not only provide the highest clearance around the filaments, but also permit the spinning cabinets to be inexpensively constructed of a standard tubing or piping. The spinning cabinets may be employed singly or in groups depending upon the required capacity.

Means are provided to heat the air entering the spinning cabinet and/or to control the temperature of the air passing therethrough. The heating means may take the form of a jacket through

which a heating medium is passed, heating coils positioned inside or outside of the cabinet, electrical resistance elements or other similar means for this same purpose. If desired, the heating means may extend over the whole or only a portion of the spinning cabinet, and may be divided into a number of sections under separate control to permit a differential in temperature to be maintained at various points within said spinning cabinet. The heating means, the spinning cabinet, or both may be insulated to reduce the heat loss therefrom.

In addition to permitting spinning to be carried out at higher velocities than has hitherto been considered feasible, the process and apparatus of this invention possess a number of additional advantages. For example, the high velocity of the stream of evaporative medium increases the efficiency with which the solvent is evaporated from the filaments and thereby reduces the total length required of the spinning cabinet. Moreover, because of the lower cross-sectional area of the spinning cabinet there is a more efficient utilization of the evaporative medium flowing therethrough and as a result the concentration of solvent in the effluent medium may be increased if desired. This, in turn, permits the total volume of the material which must pass through the solvent recovery system to be reduced. The lower cross-sectional area of the spinning cabinet also reduces the total volume of the spinning cabinet and of the solvent-evaporative medium mixture contained therein, and thereby minimizes the explosion hazard. Furthermore, the lower volume of the spinning cabinet permits the acetone concentration in the evaporative medium to be increased above the explosion point eliminating the explosion hazard. Since the smaller spinning cabinet has reduced outer surfaces, the escape of heat through said surfaces is minimized and a lesser quantity of heat must be employed to raise the evaporative medium in said cabinet to the proper temperature. Because of the reduced quantity of heat lost from the spinning cabinet, a smaller air-conditioning unit will be adequate to maintain the temperature of the spinning room within a proper range. Despite their small size, the spinning cabinets of this invention may be threaded readily since the stream of evaporative medium acts as an ejector to carry the filaments downward therethrough.

In carrying out the process of this invention, we may employ any suitable filament-forming material such as, for example, cellulose acetate, cellulose propionate, cellulose butyrate, cellulose acetate-propionate, cellulose acetate-butyrate, ethyl cellulose, polyvinyl acetate, polyvinyl chloride or vinyl acetate-vinyl chloride copolymer. The filament-forming material may be dissolved in a suitable solvent or solvent mixture such as acetone, ethylene dichloride, methylene chloride and ethyl alcohol, chloroform and ethyl alcohol, or chloroform and methyl alcohol. While we prefer to employ air as the evaporative medium, since it is the least expensive and the most readily available, we may also employ other gases such as nitrogen or carbon dioxide for this purpose. In our preferred embodiment, which is described in detail below, we employ a solution of cellulose acetate in acetone as the spinning dope, and air as the evaporative medium.

The term "filaments" as employed hereinto include filaments, straw, braid, ribbon or similar articles of regular or irregular cross-section.

In the accompanying drawing, the figure is a



view in cross-section of a spinning cabinet embodying this invention.

Referring now to the drawing, the reference numeral 11 designates a spinning jet to which a heated and filtered spinning dope is supplied under pressure through a conduit 12. The spinning dope passes through the orifices in the spinning jet 11 and emerges in the form of a bundle of filaments 13, which enter a spinning cabinet, indicated generally by the reference numeral 14. The spinning jet 11 is positioned above the spinning cabinet 14 to permit the filaments 13 to pass through a region of relatively quiescent air before entering said cabinet. The spinning cabinet comprises an upper section 16, a lower section 17 of smaller diameter than the upper section 16 and an intermediate tapered section 18 between said upper and lower sections. By varying the diameter of the spinning cabinet 14 in this manner, the air viscosity in the upper section 16 through which the filaments first pass will be lower than the air velocity in the lower section 17 through which the filaments next pass and the air velocity will increase smoothly and without turbulence in the tapered section 18.

The upper section 16 of the spinning cabinet 14 is provided with jackets 19, 21 and 22 to which a heating medium may be admitted to control the temperature of the evaporative medium in the cabinet. The heating medium is admitted into the jackets 19, 21, 22 through pipes 23, 24 and 26 and leaves said jackets through pipes 27, 28 and 29. By controlling the temperature and the rate of flow of the heating medium through each of the jackets, any desired temperature or temperature gradient may be established in the upper section 16 of the spinning cabinet 14.

At the lower end of the spinning cabinet 14 there is a chamber 31 having a hinged door 32 provided with an aperture 33 through which the filaments 13 are drawn by means of the feed roller 34. The filaments may then be twisted and packaged or treated in any other manner to put them in condition for further use.

The chamber 31 is provided with a pipe 36 by means of which the air may be exhausted from the spinning cabinet 14 to a suitable solvent recovery system (not shown). The exhaust system causes the stream of air entering the open upper end of the spinning cabinet 14 to flow downwardly through said cabinet in the direction of travel of the filaments 13. By regulating the quantity of air exhausted through the pipe 36 in any desired manner, the velocity of the air in the spinning cabinet may be adjusted over a wide range.

The following example is given to further illustrate this invention.

*Example*

A spinning dope comprising a solution of cellulose acetate in acetone is filtered and heated and pumped through a spinning jet containing 40 spinning orifices 0.042 inch in diameter. The filaments leaving said spinning jet are passed into the spinning cabinet 14 through which a stream of air having an average velocity of 1200 meters per minute flows. To heat the incoming stream of air, steam at a pressure of about 130 pounds per square inch above atmospheric and at a temperature of about 175° C. is admitted into the jackets 19, 21 and 22. After passing through the spinning cabinet, the filaments are drawn from said cabinet at a velocity of about 1400 meters per minute, have a twist imparted thereto and are wound onto a package. The filaments

have a tenacity of about 1.05 grams per denier and an elongation of over 15% when stressed to the breaking point. Attempts to spin filaments at the same speed without the high-velocity stream of air through the spinning cabinet were completely unsuccessful since the filaments were immediately broken by the excessive stresses to which they were subjected.

While this invention has been described with particular reference to the spinning of filaments at high velocities, it is also useful when spinning is carried out at low velocities, i. e. below about 800 meters per minute. Thus, by maintaining the velocity of the stream of evaporative medium within the limits hereinbefore set forth, when spinning at low velocities the filaments produced will exhibit improved physical properties such as an increased elongation under stress.

It is to be understood that the foregoing detailed description is given merely by way of illustration and that many variations may be made therein without departing from the spirit of our invention.

Having described our invention, what we desire to secure by Letters Patent is:

1. In a dry-spinning process for the production of artificial filaments from a spinning dope containing a filament-forming material and a volatile solvent, the steps which comprise forming filaments from said spinning dope, passing the solvent containing filaments through a spinning cabinet, and passing a stream of an evaporative medium through said spinning cabinet in the direction of travel of the filaments to evaporate the solvent therefrom, the speed of the filaments through said spinning cabinet being above about 800 meters per minute and the velocity of the air stream through said spinning cabinet being lower than the speed of the filaments but above about 280 meters per minute whereby no excessive stresses are imposed upon the filaments leaving said spinning cabinet as the result of the high speed of the filaments through said spinning cabinet.

2. In a dry-spinning process for the production of artificial filaments from a spining dope containing a filament-forming material and a volatile solvent, the steps which comprise forming filaments from said spinning dope, passing the solvent containing filaments through a spinning cabinet, and passing a stream of an evaporative medium through said spinning cabinet in the direction of travel of the filaments to evaporate the solvent therefrom, the speed of the filaments through said spinning cabinet being between about 800 and 1400 meters per minute and the velocity of the air stream through said spinning cabinet being between about 280 and 1300 meters per minute with the difference in velocity between the filaments and the stream of evaporative medium being at most 600 meters per minute, the speed of the filaments being greater than the velocity of the air stream, whereby no excessive stresses are imposed upon the filaments leaving said spinning cabinet as the result of the high speed of the filaments through said spinning cabinet.

3. In a dry-spinning process for the production of artificial filaments from a spinning dope containing a filament-forming material and a volatile solvent, the steps which comprise forming filaments from said spinning dope, passing the solvent containing filaments through a spinning cabinet, and passing a stream of an evaporative medium through said spinning cabinet in the direction of travel of the filaments to evaporate the solvent therefrom, the speed of the filaments through said spinning cabinet being above about 800 meters per minute and the velocity of the stream of evaporative medium through said spinning cabinet being above about 280 meters per minute but of such velocity that the difference in velocity between the filaments and the stream of evaporative medium does not exceed about 600 meters per minute.

4. In a dry-spinning process for the production of artificial filaments from a spinning dope containing a filament-forming material and a volatile solvent, the steps which comprise forming filaments from said spinning dope, passing the solvent containing filaments through a spinning cabinet, and passing a stream of an evaporative medium through said spinning cabinet in the direction of travel of the filaments to evaporate the solvent therefrom, the speed of the filaments through the spinning cabinet being above about 800 meters per minute so that the tension of the filaments leaving the spinning cabinet would be above about 0.2 gram per denier in the absence of the stream of evaporative medium and the velocity of the air stream through said spinning cabinet being between about 35 and 95% of the speed of the filaments through said spinning cabinet whereby no excessive stresses are imposed upon the filaments leaving said spinning cabinet.

5. In a dry-spinning process for the production of artificial filaments from a spinning dope containing a filament-forming material and a volatile solvent, the steps which comprise forming filaments from said spinning dope, passing the solvent containing filaments through a spinning cabinet and passing a stream of an evaporative medium through said spinning cabinet in the direction of travel of the filaments to evaporate the solvent therefrom, the speed of the filaments through said spinning cabinet being above about 800 meters per minute, and the velocity of the air stream through said spinning cabinet being lower than the speed of the filaments passing through said spinning cabinet but above about 35% of the speed of the filaments whereby no excessive stresses are imposed upon the filaments leaving said spinning cabinet as the result of the high speed of the filaments through said spinning cabinet.

6. In a dry-spinning process for the production of artificial filaments from a spinning dope containing a filament-forming material and a volatile solvent, the steps which comprise forming filaments from said spinning dope, passing the solvent containing filaments through a spinning cabinet, and passing a stream of an evaporative medium through said spinning cabinet in the direction of travel of the filaments to evaporate the solvent therefrom, the speed of the filaments through said spinning cabinet being between about 800 and 1400 meters per minute, and the velocity of the air stream through said spinning cabinet being between about 35 and 95% of the speed of the filaments through said spinning cabinet whereby no excessive stresses are imposed upon the filaments leaving said spinning cabinet as the result of the high speed of the filaments through said spinning cabinet.

7. In a dry-spinning process for the production of artificial filaments from a spinning dope containing a filament-forming material and a volatile solvent, the steps which comprise forming filaments from said spinning dope, passing the solvent containing filaments through a spinning

cabinet, and passing a stream of an evaporative medium through said spinning cabinet in the direction of travel of the filaments to evaporate the solvent therefrom, the speed of the filaments through said spinning cabinet being above about 800 meters per minute and the velocity of the air stream through said spinning cabinet being lower than the speed of the filaments but above about 280 meters per minute whereby no excessive stresses are imposed upon the filaments leaving said spinning cabinet as the result of the high speed of the filaments through said spinning cabinet, the evaporative medium through which the filaments pass after they are formed being relatively quiescent, and the evaporative medium through which the filaments next pass before entering the high velocity stream of evaporative medium having a velocity sufficiently low as to cause no coalescence of the newly formed filaments.

8. In a dry-spinning process for the production of artificial filaments from a spinning dope containing a filament-forming material and a volatile solvent, the steps which comprise forming filaments from said spinning dope, passing the solvent containing filaments through a spinning cabinet, and passing a stream of an evaporative medium through said spinning cabinet in the direction of travel of the filaments to evaporate the solvent therefrom, the speed of the filaments through said spinning cabinet being above about 800 meters per minute and the velocity of the air stream through said spinning cabinet being lower than the speed of the filaments but above about 280 meters per minute whereby no excessive stresses are imposed upon the filaments leaving said spinning cabinet as the result of the high speed of the filaments through said spinning cabinet, the evaporative medium through which the filaments pass after they are formed being relatively quiescent, and the evaporative medium through which the filaments next pass before entering the high-velocity stream of evaporative medium having a lower velocity than said high velocity stream whereby no coalescence of the newly formed filaments occurs.



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