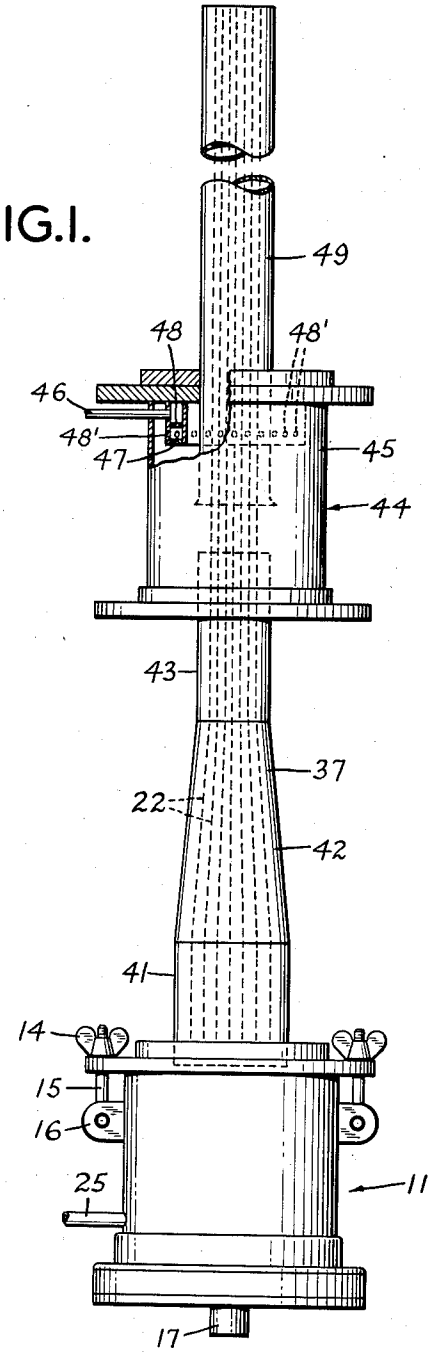
Jan. 31, 1956 W. H. BRADSHAW ET AL 2,732,586

SPINNING OF FILAMENTARY MATERIALS

Filed April 30, 1952 2 Sheets-Sheet 1

FIG.I.



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2 Sheets-Sheet 2

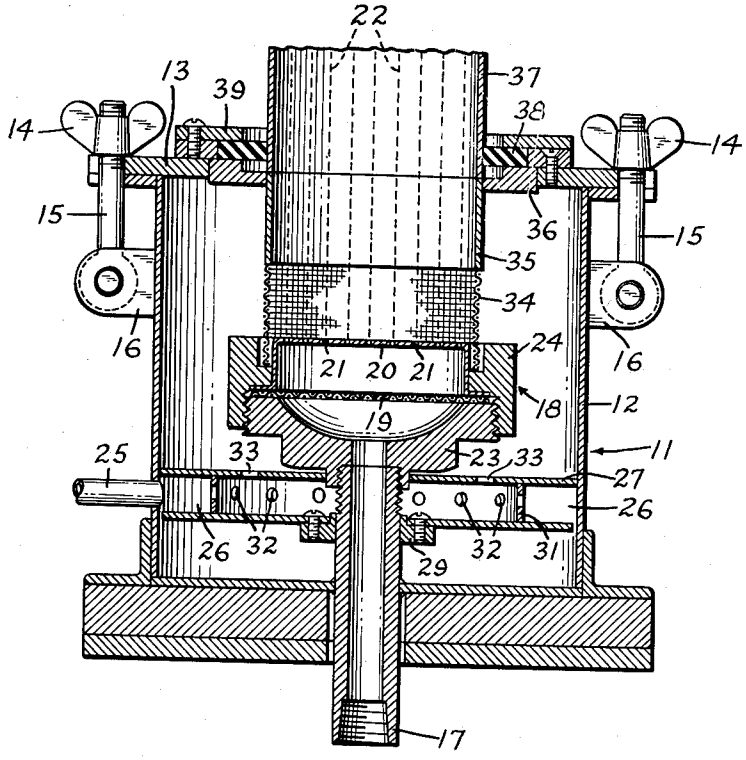


FIG. 2.

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United States Patent Office 2,732,586 Patented Jan. 31, 1956

2,732,586

SPINNING OF FILAMENTARY MATERIALS

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Application April 30, 1952, Serial No. 285,238

14 Claims. (Cl. 18—8)

This invention relates to the spinning of filamentary materials and is particularly concerned with the wet-spinning of filamentary materials having a basis of an organic acid ester of cellulose.

An important object of this invention is to provide a process and apparatus for the wet-spinning of filamentary materials having a basis of an organic acid ester of cellulose which will consistently yield products having uniform, desirable properties.

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.

In the production of high tenacity organic derivative of cellulose filamentary materials by the wet-spinning process, a spinning dope comprising a solution of an organic derivative of cellulose material is pumped or otherwise forced through a spinnerette, containing one or more apertures therein, into a liquid coagulating medium containing a solvent or plasticizing agent, hereinafter referred to as a plasticizing agent, for the organic derivative of cellulose. As the filaments flow through the coagulating medium, a sufficient tension is applied thereto to cause the filamentary materials to stretch, the degree of stretch determining to a large extent the properties of the final products. The organic derivative of cellulose filamentary materials prepared in this manner may be used as such or they may be saponified, in a manner well known in the art, further to increase their tenacity.

It has now been found that close control must be maintained over the conditions during each part of the spinning operation to obtain products having uniform, desirable properties. As the filamentary materials emerge from the spinnerette, which is preferably of the type shown in the copending application of R. O. Denyes, Serial No. 224,352, filed May 3, 1951, now Patent No. 2,673,368, into a spin pot through which the coagulating medium flows, care must be taken substantially to prevent disturbance of the filamentary materials and the coagulating medium immediately surrounding them if undesirable variations in the properties of the filamentary material are to be avoided. An arrangement that has been found suitable for substantially preventing the development of turbulence in the coagulating medium, comprises an annular distributing head which will discharge the coagulating medium into the spin pot at a plurality of points spaced about its periphery, together with a screen which encloses the spinnerette and through which the coagulating medium must flow to come into contact with the filamentary materials. The filamentary materials and the coagulating medium are then caused to flow upwardly through a spin tube into a second spin pot into which a further quantity of coagulating medium is introduced, again taking care to obtain a uniform distribution of the coagulating medium as it enters the second spin pot and

approaches the filamentary materials. From the second spin pot, the filamentary materials and all the coagulating medium flow upwardly into a second spin tube wherein the coagulation of the filamentary materials is completed to the desired extent. To impart the desired degree of stretch to the filamentary materials, which may range from about 500 to 12,800%, or more, means, of any conventional type, are provided to control the rate of delivery of the spinning dope through the spinnerette and to control the rate of withdrawal of the filamentary materials from the second spin tube.

As will be described more fully hereinafter, it has been found essential, in order to obtain filamentary materials having uniform, desirable properties, to employ spin tubes having an internal diameter bearing a definite relationship to the diameter of the bundle of filaments being produced and to maintain a definite relationship between the velocity of the filamentary materials and the stream of coagulating medium flowing through the spin tubes.

Among the organic derivative of cellulose materials that may be employed for the production of filamentary materials in this manner, there may be mentioned cellulose acetate, cellulose propionate, cellulose butyrate, cellulose acetate propionate, cellulose acetate butyrate and the like. These organic derivatives of cellulose materials may be dissolved in any suitable solvents, including, for example, acetone-water mixtures, diacetone, nitromethylene, acetic acid, methyl acetate, various chlorinated hydrocarbons especially in conjunction with alcohol such as methylene chloride, ethyl chloride, etc. and methyl ethyl ketone to form the spinning dope. The coagulating medium may be aqueous or non-aqueous in nature and may contain, as the plasticizing agent for the organic derivative of cellulose material, any suitable substance, such as, for example, acetone, diacetone alcohol, acetic acid, formic acid, ethyl lactate, zinc chloride, thiocyanates, such as sodium, potassium or ammonium thiocyanate and various chlorinated hydrocarbons such as methylene chloride, ethyl chloride and mixtures of chlorinated hydrocarbons.

A preferred embodiment of this invention is shown in the accompanying drawings wherein—

Fig. 1 is a front elevational view of the spinning apparatus, and

Fig. 2 is a cross-sectional view, on an enlarged scale, of the lower spin pot.

Referring now to the drawings, the reference numeral **11** designates generally a lower spin pot comprising a cylindrical chamber **12** to the top of which a cover **13** is secured by means of wing nuts **14** and bolts **15** mounted in pad eyes **16** fastened to the walls of the said chamber **12**. A spinning dope is pumped into the lower spin pot **11** through a conduit **17** which discharges into a spinning head, indicated generally by reference numeral **18**. The spinning head **18** comprises a filter unit **19** and a spinnerette **20** having a plurality of apertures **21** therein through which filaments **22** emerge. The filter unit **19** and the spinnerette **20** are mounted between a lower fitting **23** secured to the conduit **17** and an upper fitting **24** in threaded engagement with the lower fitting **23**, the two fittings together forming the casing of the spinning head **18**.

A coagulating or setting medium, which will cause the filaments **22** to coagulate or set, is introduced into the lower spin pot **11** through a conduit **25** which discharges the said coagulating medium into an annular distributing head **26** extending around the periphery of the chamber **12**. The annular distributing head **26** is formed by an upper plate **27** which extends from the wall of the chamber **12** to the lower fitting **23**, a lower plate **28** which ex-

tends from a point slightly spaced from the wall of the chamber **12** to a fitting **29** fastened to the conduit **17**, and a cylindrical tube **31** that is positioned concentrically of the wall of the chamber **12** and extends from the upper plate **27** to the lower plate **28**. After filling the annular passageway **26**, the coagulating medium flows through a plurality of apertures **32** in the cylindrical tube **31** and then upwardly through a plurality of apertures **33** in the upper plate **27** to fill the main body of the chamber **12**. From the chamber **12**, the coagulating medium flows through a cylindrically shaped screen **34**, which surrounds the spinnerette **20**, and then flows upwardly, with the filaments **22**, through a tube **35** which is suspended from the cover **13** by means of an adapter ring **36**. By bringing the coagulating medium into contact with the filaments **22** in the manner described, the development of turbulence in the said medium is substantially prevented, thereby insuring that the coagulation of all the filaments **22** will take place under substantially uniform conditions.

The filaments **22** and the coagulating medium then flow upwardly through a lower spin tube **37** which extends through a gasket **38**, maintained in position by means of a ring **39**, into abutment with the tube **35**. The lower spin tube **37** consists of three sections, a bottom cylindrical section **41**, an intermediate inwardly tapered section **42**, and an upper cylindrical section **43**. The dimensions of the lower spin tube **37**, as well as of the screen **34** and the tube **35**, must be maintained within close limits relative to the diameter of the bundle of filaments **22** to obtain filaments having uniform, desirable properties. In general, the internal diameter of the lower spin tube **37**, the screen **34** and the tube **35** should exceed the diameter of the bundle of filaments **22** by at most about 1 inch at any point along the length of any of its three sections. It has been found that when there is a greater difference between the internal diameter of the lower spin tube **37** and the diameter of the bundle of filaments **22**, there is a tendency for circulatory currents to develop between the bundle of filaments and the wall of the spin tube, which will affect the properties of at least some of the filaments **22** in an undesirable manner. In addition, it has been found that the best results are obtained when the spin tube **37** is tapered inwardly along its length so as to reduce its internal diameter at a distance of between about 10 and 25 inches from the face of the spinnerette **20** to between about 50 and 85% of its internal diameter adjacent to the spinnerette.

The filaments **22** and the coagulating medium emerge from the lower spin tube **37** into an upper spin pot, indicated generally by reference numeral **44**, comprising a cylindrical chamber **45** into which the lower spin tube **37** projects for a short distance. An additional quantity of coagulating medium is introduced into the upper spin pot **44** through a conduit **46** into the upper portion of an annular distributing head **47** provided with a plurality of perforations **48** leading to the lower portion thereof from which the coagulating medium flows into the upper spin pot **44** through perforations **48'** distributed about the outer periphery of the said annular distributing head **47**. The head **47** serves to reduce to a minimum the disturbance of the filamentary materials by supplying the additional coagulating medium uniformly around the entire bundle of filamentary materials. The filaments **22** and all the coagulating medium flow from the upper spin pot **44** into an upper spin tube **49** which is aligned with the lower spin tube **37** and which projects through the top of and into the upper spin pot **44**. Advantageously, the upper spin tube **49** is positioned so that its lower end is spaced between about ½ and 2½ inches from the upper end of the lower spin tube **37**. The internal diameter of the upper spin tube **49** should be equal, in general, to the internal diameter of the upper end of the lower spin tube **37**.

Upon emergence from the upper spin tube **49**, the filaments **22** may be separated from the coagulating medium in any suitable manner, as for example, by means of the

apparatus disclosed in the application of Edward T. Jones, Jr., Serial No. 261,439, filed December 13, 1951, now Patent No. 2,674,112. The filaments **22** may then be washed, dried and wound into a package, or they may be continuously saponified, washed and dried before being wound into a package, all in a manner well known in the art.

The distribution of apertures **21** in the face of the spinnerette **20** can take a number of different patterns. However, for spinnerettes having more than about 300 apertures therein, the best results are obtained when the apertures are arranged in the manner disclosed in the Denyes application referred to above. When using this arrangement, spinnerettes having up to 300 apertures preferably have a 1.5 inch diameter face; spinnerettes having over 300 and up to 550 apertures preferably have 2 inch diameter face; spinnerettes having over 550 and up to 1400 apertures preferably have a 3 inch diameter face; and spinnerettes having over 1400 apertures have a 4 inch, or larger, diameter face. The diameter of the spinnerette face may be expressed by the equation

$$d=0.25+\sqrt{\frac{N}{186}}\pm 0.5$$

where d equals the diameter of the spinnerette face in inches and N equals the number of apertures. The internal diameter of the lower end of the lower spin tube **37** is defined by the same equation.

To obtain filamentary materials having the most desirable properties, the internal diameter of the upper end of the lower spin tube **37** should bear a definite relationship to the internal diameter of the lower end of said lower spin tube. This relationship may be expressed by the formula

$$d'=(0.67 \pm 0.17)d$$

where d' equals the internal diameter of the upper end of the lower spin tube and d has the meaning given above. The internal diameter of the lower end of the upper spin tube **49** is defined by the same equation.

The amount of coagulating medium introduced into the lower spin pot **11** should be controlled to give a definite concentration of solvent and plasticizing agent around each of the filaments **22**, particularly for a distance of about 5 inches upwardly from the point where the filaments **22** emerge from the spinnerette **20** to obtain products having the most desirable properties. It has been found that if an insufficient amount of coagulating medium is introduced into the lower spin pot **11**, the filaments **22** tend to break, interrupting the continuity of spinning. It has also been found that if the amount of coagulating medium introduced into the lower spin pot **11** is increased to at least about the minimum necessary to avoid breakage of the filaments **22** or preferably to about said minimum, products are obtained having the optimum physical properties. The amount of coagulating medium may be expressed by the equation

$$C=3N\pm N$$

where C equals the amount of coagulating medium in cubic centimeters per minute and N has the meaning given above. When the number of filaments being spun is less than $186(d-0.25)^2$ the amount of coagulating medium used should be the same as when the number of filaments is equal to $186(d-0.25)^2$.

The additional coagulating medium introduced into the upper spin pot **44** enables a close control to be obtained of the temperature and concentration of solvent and plasticizing agent during the later stages of the setting of the filaments **22**. Also by increasing the velocity of the coagulating medium in the upper spin tube **49** with respect to the velocity of the filaments **22**, the tension on the said filaments **22** as they leave the coagulating medium is reduced. The increased velocity of the coagulating medium in the upper spin tube **49** also serves to maintain the filaments **22** in a straight line as

they pass through the upper spin pot 44 from the lower spin tube 27 to the upper spin tube 49.

The following examples are given to illustrate this invention further.

Examples

A spinning dope containing 20% by weight of cellulose acetate dissolved in a mixture of 90 parts by volume of acetone and 10 parts by volume of water is spun into a coagulating medium comprising a mixture of 27 parts by volume of acetone and 73 parts by volume of water and maintained at 60° C. The spinning conditions are as set forth in the following table:

	1	2
Filament speed at take-up, meters/min.	75	75
Number of apertures in spinnerette	300	1,400
Denier per filament	.85	.85
Diameter of spinnerette face, inches	1.5	3
Internal diameter of lower end of lower spin tube, inches	1.5	3
Internal diameter of upper end of lower spin tube, inches	1	2
Coagulating medium added to lower spin pot, cc./min.	900	4,200
Coagulating medium added to upper spin pot, cc./min.	1,500	1,500

In both cases the spinning continues without interruption and there is obtained a product having good physical properties.

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 an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, means for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, and a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, the internal diameter of said spin tube exceeding the diameter of the bundle of filaments by at most about 1 inch at any point along its length.

2. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, means for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, and a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, the internal diameter of the said spin tube exceeding the diameter of the bundle of filaments by at most about 1 inch at any point along its length and the said spin tube tapering inwardly along its length so that its internal diameter at a distance of between about 10 and 25 inches from the face of the spinnerette is between about 50 and 85% of its internal diameter adjacent to the spinnerette.

3. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, means for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, a screen surrounding the spinnerette through which the coagulating medium flows into contact with the bundle of filaments, and a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, the internal diameter of the said spin tube and the said screen exceeding the diameter of the bundle of filaments by at most about 1 inch at any point along its length.

4. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, an annular distributing head having a plurality of perforations about the periphery thereof positioned in said spin pot for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, a screen surrounding the spinnerette through which the coagulating medium flows into contact with the bundle of filaments, and a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, the internal diameter of the said spin tube and the said screen exceeding the diameter of the bundle of filaments by at most about 1 inch at any point along its length.

5. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, means for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, a second spin pot into which the coagulating medium and the bundle of filaments pass from the spin tube, means for introducing a further quantity of coherent liquid coagulating medium into said second spin pot, and a second spin tube extending from the second spin pot through which all coagulating medium and the bundle of filaments pass upwardly from the second spin pot, the inlet end of the said second spin tube being spaced between about ½ and 2½ inches from the outlet end of the first spin tube.

6. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, means for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, a second spin pot into which the coagulating medium and the bundle of filaments pass from the spin tube, means for introducing a further quantity of coherent liquid coagulating medium into said second spin pot, and a second spin tube extending from the second spin pot through which all the coagulating medium and the bundle of filaments pass upwardly from the second spin pot, the internal diameter of the said spin tubes exceeding the diameter of the bundle of filaments by at most about 1 inch at any point along their length.

7. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, an annular distributing head having a plurality of perforations about the periphery thereof positioned in said spin pot for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming

apertures in the spinnerette into the coagulating medium to form a bundle of filaments, a screen surrounding the spinnerette through which the coagulating medium flows into contact with the bundle of filaments, a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, the internal diameter of the said screen and of the said spin tube exceeding the diameter of the bundle of filaments by at most about 1 inch at any point along their length, the said spin tube tapering inwardly along its length so that its internal diameter at a distance of between about 10 and 25 inches from the face of the spinnerette is between about 50 and 85% of its internal diameter adjacent to the spinnerette, a second spin pot into which the coagulating medium and the bundle of filaments pass from the spin tube, means for introducing a further quantity of coherent liquid coagulating medium into said second spin pot, and a second cylindrical spin tube extending from the second spin pot through which all the coagulating medium and the bundle of filaments pass upwardly from the second spin pot, the inlet end of said second spin tube being spaced between about ½ and 2½ inches from the outlet end of the first spin tube and the internal diameter of the said second spin tube exceeding the diameter of the bundle of filaments by at most about 1 inch at any point along its length.

8. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, means for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, and a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, the diameter of the spinnerette face being expressed by the equation

$$d=0.25+\sqrt{\frac{N}{186}}\pm 0.5$$

where d is the diameter of the spinnerette face in inches and N is the number of filament-forming apertures in the spinnerette.

9. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, means for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, and a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, the internal diameter of the lower end of the spin tube being expressed by the equation

$$d=0.25+\sqrt{\frac{N}{186}}\pm 0.5$$

where d is the internal diameter of the lower end of the spin tube in inches and N is the number of filament-forming apertures in the spinnerette.

10. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, means for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, and a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, the internal diameter of the lower end of the spin tube being expressed by the equation

$$d=0.25+\sqrt{\frac{N}{186}}\pm 0.5$$

where d is the internal diameter of the lower end of the spin tube in inches and N is the number of filament-forming apertures in the spinnerette, and where the internal diameter of the upper end of the spin tube is expressed by the equation

$$d'=(0.67\pm 0.17)d$$

where d' is the internal diameter of the upper end of the spin tube in inches.

11. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, means for introducing a coherent mass of liquid coagulating medium into said pin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, a second spin pot into which the coagulating medium and the bundle of filaments pass from the spin tube, means for introducing a further quantity of coherent liquid coagulating medium into said second spin pot, and a second cylindrical spin tube extending from the second spin pot through which all the coagulating medium and the bundle of filaments pass upwardly from the second spin pot, the internal diameter of the lower end of the lower spin tube being expressed by the equation

$$d=0.25+\sqrt{\frac{N}{186}}\pm 0.5$$

where d is the internal diameter of the lower end of the lower spin tube in inches and N is the number of filament-forming apertures in the spinnerette.

12. In an apparatus for the spinning of filamentary materials, the combination with a spin pot, of a spinning head including a spinnerette having at least 300 filament-forming apertures therein, means for introducing a coherent mass of liquid coagulating medium into said spin pot, means for introducing a spinning dope into the spinning head whereby it will flow through the filament-forming apertures in the spinnerette into the coagulating medium to form a bundle of filaments, a spin tube through which the coagulating medium and the bundle of filaments pass upwardly from the spin pot, a second spin pot into which the coagulating medium and the bundle of filaments pass from the spin tube, means for introducing a further quantity of coherent liquid coagulating medium into said second spin pot, and a second cylindrical spin tube extending from the second spin pot through which all the coagulating medium and the bundle of filaments pass upwardly from the second spin pot, the internal diameter of the lower end of the lower spin tube being expressed by the equation

$$d=0.25+\sqrt{\frac{N}{186}}\pm 0.5$$

where d is the internal diameter of the lower end of the lower spin tube in inches and N is the number of filament-forming apertures in the spinnerette, and where the internal diameter of the upper end of the lower spin tube is expressed by the equation

$$d'=(0.67\pm 0.17)d$$

where d' is the internal diameter of the upper end of the spin tube in inches.

13. In a process for the production of filamentary materials by the spinning of a dope comprising a solution of an organic derivative of cellulose into a coherent mass of

liquid coagulating medium containing a plasticizing agent for the organic derivative of cellulose, the steps which comprise passing said dope through a spinnerette having at least 300 apertures therein into an enclosed coagulating zone to form a bundle of filaments, introducing a liquid coagulating medium into the coagulating zone around said spinnerette so as to envelop each of the newly formed filaments in said bundle with a coherent liquid mass, and passing said newly formed bundle and the coagulating medium from said coagulating zone upwardly through an elongated passageway having an internal diameter exceeding the diameter of said bundle of filaments by at most about 1 inch at any point along its length.

14. In a process for the production of filamentary materials by the spinning of a dope comprising a solution of an organic derivative of cellulose into a coherent mass of liquid coagulating medium containing a plasticizing agent for the organic derivative of cellulose, the steps which comprise passing said dope through a spinnerette having at least 300 apertures therein into an enclosed coagulating zone to form a bundle of filaments, introducing a liquid coagulating medium into the coagulating zone around said spinnerette so as to envelop each of the newly formed filaments in said bundle with a coherent liquid mass, and passing said newly formed bundle and the coagulating medium from said coagulating zone upwardly through an elongated passageway of varying cross-section, the internal diameter of said passageway exceeding the diameter of said bundle by at most about 1 inch at any point along its length, the internal diameter of

the end of said passageway adjacent to said spinnerette being expressed by the equation

$$d=0.25+\sqrt{\frac{N}{186}}+0.5$$

where d is said internal diameter in inches and N is the number of filaments in said bundle, the internal diameter of the other end of said passageway being expressed by the equation

$$d'=(0.67\pm0.17)d$$

where d' is said internal diameter in inches, the amount of coagulating medium passing through said passageway being defined by the equation

$$C=3N\pm N$$

where C is the amount of coagulating medium in cubic centimeters per minute, passing said bundle and all the coagulating medium upwardly through a second passageway and introducing a further amount of coherent liquid coagulating medium into said second passageway.

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