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MELT SPINNING APPARATUS

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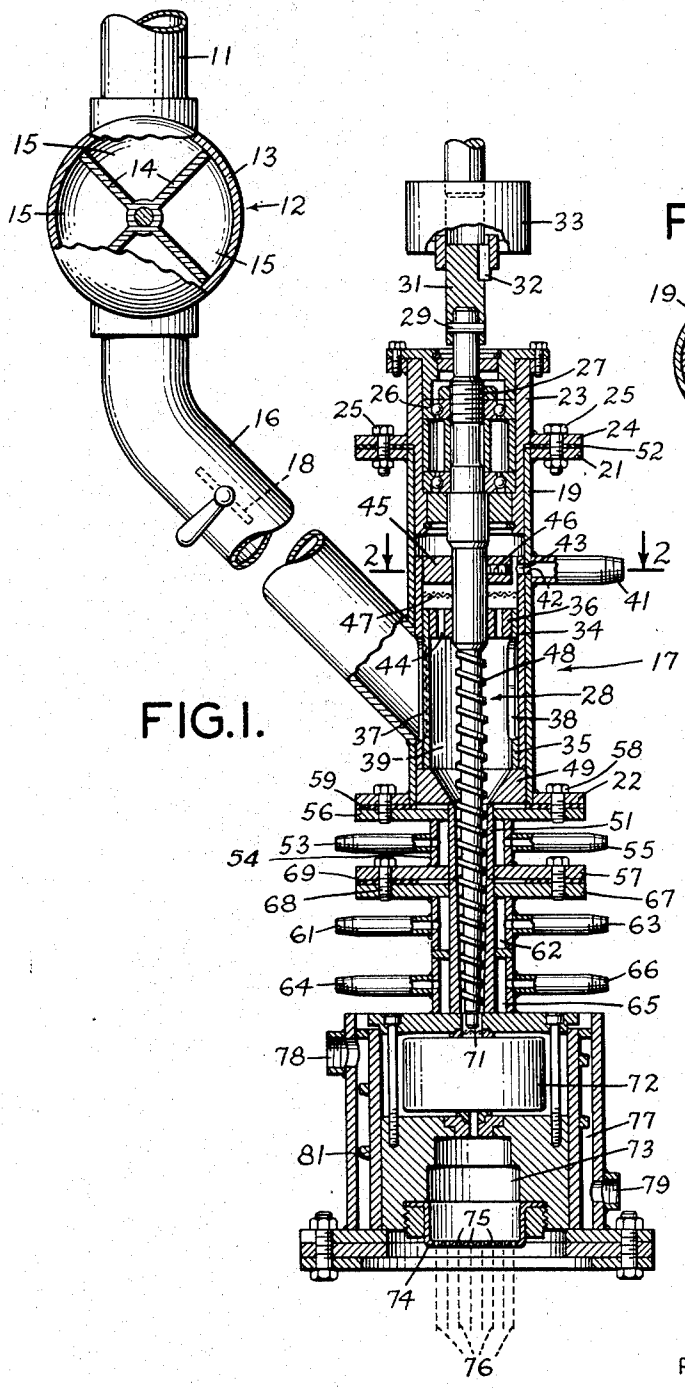


FIG.1.

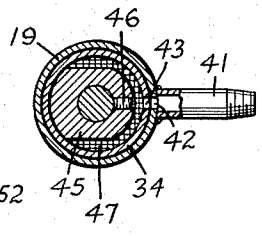


FIG.2.

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MELT SPINNING APPARATUS

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6 Claims. (Cl. 18—8)

This invention relates to spinning and relates more particularly to an improved process and apparatus for the production of filamentary materials by the melt-spinning of a filament-forming material.

In the production of filamentary materials, particularly multi-filament filamentary materials such as yarn and the like, by the melt-spinning process, a filament-forming material is raised to a temperature above its melting point and the molten material is then pumped through a spinnerette containing a plurality of spinning apertures therein. The filamentary materials emerge from the spinnerette into a cooling medium, such as air, wherein they are cooled rapidly to a temperature below the melting point of the filament-forming material thereby causing the filamentary materials to set. The uniformity of the filamentary materials depends upon three factors; the uniformity in the volume rate at which the filament-forming material is forced through the apertures in the spinnerette, the uniformity in the density of the filament-forming material and the uniformity of the heating of the filament-forming material. Through the use of suitably designed pumping means, the volume rate at which the filament-forming material is forced through the apertures in the spinnerette may be held substantially constant within extremely narrow limits. To bring the filament-forming material to a uniform density, however, presents a number of problems. Voids in the filament-forming material must be eliminated therefrom. In addition, gases and water vapor must be removed from the filament-forming material since their presence would cause an effective change in the uniformity of the filamentary materials being produced. The low heat conductivity of the filament-forming material makes it difficult to heat the said material to a uniform temperature.

According to prior melt-spinning processes, the filament-forming material is brought to a molten state and is then cooled until it solidifies, either during its production or at some other point in its processing prior to the spinning operation itself. As a result, the filament-forming material employed for spinning is relatively dense and free from voids. In addition, it is the practice during the spinning operation to establish a relatively large pool of molten filament-forming material and to draw the filament-forming material from said pool as required during spinning. The filament-forming material tends to reach a substantially uniform density during the period of time it remains in the molten state in said pool. It is possible through the use of one or both of the foregoing expedients to obtain filamentary materials of a high degree of uniformity. There is, however, a considerable tendency for the filament-forming material to decompose or degrade both during the preliminary melting of the said material and during the relatively long period of time it remains in a molten state during the spinning operation. This tendency to decompose or degrade is particularly marked with certain types of filament-forming material causing a serious loss of desirable properties in the final products. Despite the long period of time for which the filament-forming material is in the molten state, it does not always reach a uniform temperature. Moreover, when the filament-forming materials are not normally brought to a molten state during their production, but are obtained in a relatively bulky form containing a large number of voids and of low density, the necessity for carrying out the preliminary melting not only tends to cause the filament-forming material to decompose or degrade, but also adds to the complexity and expense of the entire process.

It is an important object of this invention to provide a process and apparatus for the production of filamentary materials by the melt-spinning of a filament-forming material which will be free from the foregoing and other difficulties and which will be especially efficient in operation and simple in construction.

A further object of this invention is to provide a process and apparatus for the production of filamentary materials by the melt-spinning of a filament-forming material wherein the filament-forming material is melted and brought to a uniform density and temperature and is forced through the apertures in a spinnerette in one continuous operation.

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.

According to the present invention there is provided an apparatus comprising a chamber having means for the introduction of a filament-forming material. The chamber is also provided with means for applying a vacuum thereto whereby gases and water vapor may be removed from the filament-forming material. To assist in the removal of gases and water vapor from the filament-forming material, it is desirable to heat the chamber to a temperature above that at which water boils under the particular degree of vacuum applied, but below that at which the filament-forming material melts. For example, when a vacuum of 28 inches of mercury is applied to the chamber, the temperature of said chamber may be maintained at between about 65 and 95° C. Positioned within the chamber is a feed screw which moves the filament-forming material, which is in an unmolten state, from the chamber into a heated jacket which is fitted closely to the feed screw and in which the filament-forming material is melted. The feed screw is designed so that it will tend to feed a substantially larger volume of filament-forming material into the entrance to said jacket than out of the discharge from said jacket. As a result, considerable pressure will be applied to the filament-forming material thereby tending to remove all voids therefrom and bringing the same to a substantially uniform density. The ratio of feeds by volume to the inlet to and from the discharge from said jacket should be at least equal to the inverse ratio of the specific gravities of the filament-forming material at the point where it enters the jacket in an unmolten state to that at the point where it leaves the jacket in the molten state. Advantageously the ratio of feeds is at least about 5% in excess of this value or between about 5 and 25% in excess of this value to compensate for any irregularities in the specific gravity of the unmolten filament-forming material. Higher ratios may also be employed if provision is made to permit slippage of the material between the screw and the jacket to avoid the development of excessive pressures. A particularly desirable way of achieving this ratio of feeds is to taper the flight of the feed screw toward its discharge end while leaving the root diameter of the feed screw unchanged. With this construction it is also possible to reduce the thickness of the filament-forming material to an extremely low value, say less than about 0.03 inches; so that all of said filament-forming material will be brought to a uniform temperature. Upon leaving the jacket, the molten

filament-forming material may be passed directly, or through a filter pack, to a spinnerette having a plurality of spinning apertures therein from which it will emerge in the form of a yarn. It may, however, be desirable to pass the molten filament-forming material leaving the jacket to a gear pump which will meter the said material directly, or through a filter pack, to the spinnerette.

The process and apparatus of this invention are particularly well suited for the production of multi-filament filamentary materials in which the individual filaments have a low denier, i. e., a denier of less than about 10 or preferably less than about 5. At these low deniers, any irregularities in the feed or density of the filamentary material will result in large percentage changes in the denier of the filaments, leading to the production of products that are not commercially acceptable. Even when starting with filament-forming materials that are bulky and of non-uniform density and contain gases and water vapor it has been found possible through the use of this invention to obtain products that have a substantially uniform denier.

Filament-forming materials that may be employed in carrying out this invention include, for example, polyamides, polyurethanes, polytriazoles, polyesters and the like.

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

Fig. 1 is a side-elevational view, partly in section, of the apparatus, and

Fig. 2 is a cross-sectional view, taken on the line 2—2 in Fig. 1, in the direction of the arrows.

Referring now to the drawing, the reference numeral **11** designates a conduit through which a filament-forming material, which may be in the form of chips, flakes, powder or the like, is fed to a feed valve, indicated generally by reference numeral **12**. The feed valve **12** comprises a cylindrical casing **13** in which is rotatably positioned a pair of intersecting plates **14** that divide the casing into quadrants **15**. The pair of plates **14** is rotated continuously or intermittently during operation by any suitable means (not shown). The upper quadrant **15** is filled with filament-forming material from the conduit **11**. As the pair of plates **14** rotates, this quadrant will be moved to the lowermost position so that the filament-forming material will be discharged from said quadrant into a conduit **16** which leads the filament-forming material to the main portion of the spinning apparatus, indicated generally by reference numeral **17**. The conduit **16** is provided with a cut-off valve **18** whereby the feed of filament-forming material to the spinning apparatus **17** may be interrupted at any time.

The spinning apparatus **17** comprises a tubular member **19** having flanges **21** and **22** secured to its upper and lower ends, respectively. A tubular fitting **23** having a flange **24** extending around its periphery projects into the upper end of the tubular member **19** and is secured in place by means of bolts **25** that extend through the flanges **21** and **24**. The tubular fitting **23** carries a plurality of anti-friction bearings **26** in which is rotatably mounted the shank **27** of a feed screw, indicated generally by reference numeral **28**. The shank **27** of the feed screw **28** is fastened by means of a pin **29** to a stub shaft **31** which is keyed by means of a key **32** to a drive coupling **33** driven by a suitable means (not shown) to rotate the feed screw **28**.

Positioned internally of the tubular member **19** below the tubular fitting **23** is a second tubular member **34**. A tubular sleeve **35**, secured to a disc **36** fastened to the feed screw **28** for rotation therewith, rides internally of the tubular member **34**, being lapped or otherwise closely seated in said tubular member so as to produce an air tight seal with said member. The tubular member **34** which is stationary, is provided with an opening **37** in its side to which the filament-forming material is directed by the conduit **16**. A similar opening **38** is provided in the side of the tubular sleeve **35** so that when the rotation of the sleeve **35** brings the openings **37** and **38** into alignment, a charge of filament-forming material will enter chamber **39** formed by the said sleeve. When the openings **37** and **38** are not in alignment, the chamber **39** will be sealed from the atmosphere.

Means are provided to evacuate the chamber **39** so as to remove gases and water vapor from the filament-forming material. This means comprises a vacuum conduit **41** which is connected to the chamber **39** by means of apertures **42** and **43** in the walls of the tubular members **19** and **34**, respectively, and apertures **44** in the disc **36**. To keep from drawing filament-forming materials into the vacuum system and from imposing an excessive burden on the vacuum system when the openings **37** and **38** come into alignment, a block **45** is fastened by means of a set screw **46** to the feed screw **28**. The block **45** is generally of smaller diameter than the internal diameter of the tubular member **37** around the major portion of its periphery, but bears against the tubular member **34** at a point diametrically opposed to the position of the opening **38**. The block **45** is lapped or otherwise closely fitted against the tubular member **34** so as to form an air tight seal therewith. As a result, when the rotation of the feed screw **28** carries the openings **37** and **38** into alignment, the block **45** will close the aperture **43** so as to seal off the vacuum line **41** from the chamber **39**. Then, when the continued rotation of the feed screw **28** carries the openings **37** and **38** out of alignment, the block **45** will move away from the aperture **43** so as again to apply a vacuum on the chamber **39**. A screen **47** interposed between the chamber **39** and the conduit **41** further insures against any particles of filament-forming material being drawn into the vacuum system.

The filament-forming material that is introduced into the chamber **39** is moved through said chamber by the flight **48** with which the lower portion of the feed screw **28** is provided. The flight **48** moves the filament-forming material through a conical adapter **49** into a jacket **51** which is fitted closely to the said flight. The jacket **51** and the flight **48** are both tapered. Because of this taper, the flight **48** will tend to feed a larger quantity by volume of filament-forming material into the entrance to the jacket **51** than through the remainder of said jacket. This will build up a pressure on the filament-forming material thereby tending to eliminate all voids therefrom. The taper of the jacket **51** and the flight **48** also permit the clearance between said members to be controlled closely in a simple manner by inserting a shim **52** of suitable thickness between the flanges **21** and **24** to shift the feed screw **28** axially of the jacket **51**. For example, if the taper of the flight **48** and the jacket **51** is $\frac{1}{50}$ and said members are in contact, a clearance of 0.0001 inch can be produced between said members by inserting a 0.005 inch shim **52** between the flanges **21** and **24** to shift the feed screw by this amount. Tapers up to about $\frac{1}{10}$ permit such close clearances between the flight **48** and the jacket **51** to be readily achieved. Because it is possible to obtain such close clearances between the flight **48** and the jacket **51**, a very efficient working of the filament-forming material can be readily achieved. The taper of the flight **48** and the jacket **51** also permit a reduction in the thickness of the molten material to insure a uniform working thereof.

The first portion of the jacket **51** through which the filament-forming material moves is heated by means of a fluid that flows through a feed pipe **53** into a chamber **54** that encircles the jacket **51** and then out of said chamber through a discharge pipe **55**. The chamber **54** is provided with upper and lower flanges **56** and **57** and is held in place by means of bolts **58** that extend through the flanges **22** and **56**. A thermal insulating gasket **59** is interposed between the flanges **22** and **56** to minimize the transfer of heat therebetween and to assure better thermal control. The first portion of the jacket **51** is heated to a temperature such as to (*a*) prevent melting

of the filament-forming material, since if such melting occurred the filament-forming material would tend to form a bridge at this point or in the conical adapter **49** and thereby interrupt continued feed of said material, and (*b*) boil off water and raise the temperature enough to remove primary gases without decomposing the material. The next portion of the jacket **51** is heated by means of a fluid that flows through a feed pipe **61** into a chamber **62** encircling said jacket and then out of said chamber through a discharge pipe **63**. The final portion of the jacket **51** is heated by means of a fluid that flows through a feed pipe **64** into a chamber **65** and then out of said chamber through a discharge pipe **66**. The chambers **62** and **65** are formed as a unit and are provided with an upper flange **67** which is secured to the flange **57** by means of bolts **68**. A thermal insulating gasket **69** is interposed between the flanges **57** and **67** to minimize the transfer of heat therebetween. Depending upon the properties of the filament-forming material, it may be desired to supply fluids having the same temperature to the chambers **62** and **65**. In some cases, it may be desirable to supply a fluid having a higher temperature to the chamber **62** so as to melt the filament-forming material quickly and then bring it to the proper spinning temperature. In still other cases, the fluid supplied to the chamber **62** may be at a lower temperature so as to begin the melting of the filament-forming material slowly.

Upon emerging from the jacket **51**, the molten filament-forming material, which now has a substantially uniform density, passes through a screen **71** to a gear pump **72**. The molten filament-forming material then flows through a filter pack **73** to a spinnerette **74** having a plurality of apertures **75** therein from which it emerges as filaments **76**. To maintain the filament-forming material at the proper spinning temperature, the gear pump **72**, the filter pack **73** and the spinnerette **74** are enclosed in a chamber **77** into which a heating fluid is introduced through a feed pipe **78** and from which it is discharged through a discharge pipe **79**. Channelling of the fluid as it flows through the chamber **77** is prevented by means of a spiral wrap of wire **81** which almost fills the space between the walls of said chamber.

Example

Particles of 4,4-polyurethane obtained by the reaction of 1,4-tetramethylene diamine with the bis-chloroformate of 1,4-butanediol, which particles have never been melted and are bulky and filled with voids, are ground to a powder which will pass an 8 mesh screen. The powder is melt spun in the apparatus shown in the accompanying drawing. There are obtained filamentary materials of substantially uniform denier and 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. An apparatus for the production of filamentary materials by the melt-spinning of a filament-forming material, comprising a chamber, means for intermittently entering a filament-forming material into said chamber, means for applying a vacuum to said chamber to remove gases and water vapor from the filament-forming material, means for automatically disconnecting the vacuum applying means from said chamber during the entrance of the filament-forming material into said chamber, a heated jacket, a feed screw for feeding the filament-forming material from said chamber to and through said jacket, whereby the filament-forming material is caused by melt and pressure is applied to the molten material to free said molten material of voids and to bring the same to substantially uniform density and a spinnerette for converting the molten filament-forming material into filamentary material.

2. An apparatus for the production of filamentary materials by the melt-spinning of a filament-forming material, comprising a chamber, means for intermittently entering a filament-forming material into said chamber, means for applying a vacuum to said chamber to remove gases and water vapor from the filament-forming material, means for automatically disconnecting the vacuum applying means from said chamber during the entrance of the filament-forming material into said chamber, a jacket, means for differentially heating said jacket whereby that part of said jacket near the entrance thereto is heated to a temperature below the melting point of the filament-forming material to prevent premature melting of said material and the remainder of said jacket is heated above the melting point of the filament-forming material, a feed screw, having the same taper as said jacket and being axially shiftable with respect to said jacket to adjust the amount of clearance therebetween, for feeding the filament-forming material from said chamber to and through said jacket, whereby the molten material is freed of voids and brought to a substantially uniform density, and a spinnerette for converting the molten filament-forming material into filamentary material.

3. An apparatus for the production of filamentary materials by the melt-spinning of a filament-forming material, comprising a chamber, means for intermittently entering a filament-forming material into said chamber, means for applying a vacuum to said chamber to remove gases and water vapor from the filament-forming material, means for automatically disconnecting the vacuum applying means from said chamber during the entrance of the filament-forming material into said chamber, a jacket, means for differentially heating said jacket whereby that part of said jacket near the entrance thereto is heated to a temperature below the melting point of the filament-forming material to prevent premature melting of said material and the remainder of said jacket is heated above the melting point of the filament-forming material, a feed screw, having the same taper as said jacket and being axially shiftable with respect to said jacket to adjust the amount of clearance therebetween, for feeding the filament-forming material from said chamber, to and through said jacket, whereby the molten material is freed of voids and brought to a substantially uniform density, a gear pump for metering the molten filament-forming material, and a spinnerette for converting the molten filament-forming material from the gear pump into filamentary material.

4. An apparatus for the production of filamentary materials by the melt-spinning of a filament-forming material, comprising a tubular member, a second tubular member positioned internally of said first tubular member, a tubular sleeve positioned internally of said second tubular member and forming a chamber for receiving the filament-forming material, means for applying a vacuum to said chamber to remove gases and water vapor from the filament-forming material, a jacket, a feed screw for feeding the filament-forming material from said chamber to and through said jacket, openings in the walls of said second tubular member and said tubular sleeve, means connecting said tubular sleeve to said feed screw whereby the rotation of the feed screw will bring said openings into alignment intermittently for permitting the filament-forming material to enter said chamber, means for heating the jacket to melt the filament-forming material, and a spinnerette for converting the molten filament-forming material into filamentary material.

5. An apparatus for the production of filamentary materials by the melt-spinning of a filament-forming material, comprising a tubular member, a second tubular member positioned internally of said first tubular member, a tubular sleeve positioned internally of said second

tubular member and forming a chamber for receiving the filament-forming material, means for applying a vacuum to said chamber to remove gases and water vapor from the filament-forming material, a jacket, a feed screw for feeding the filament-forming material from said chamber to and through said jacket, said jacket and said feed screw being tapered whereby said feed screw has a higher rate of feed at the inlet to said jacket than at the outlet from said jacket to place the filament-forming material under pressure and eliminate voids therefrom, means for shifting the feed screw axially with respect to the jacket to adjust the clearance between the jacket and the feed screw, openings in the walls of said second tubular member and said tubular sleeve, means connecting said tubular sleeve to said feed screw whereby the rotation of the feed screw will bring said openings into alignment intermittently for permitting the filament-forming material to enter said chamber, means for heating the jacket to melt the filament-forming material, and a spinnerette for converting the molten filament-forming material into filamentary material.

6. An apparatus for the production of filamentary materials by the melt-spinning of a filament-forming material, comprising a tubular member, a second tubular member positioned internally of said first tubular member, a tubular sleeve positioned internally of said second tubular member and forming a chamber for receiving the filament-forming material, means for applying a vacuum to said chamber to remove gases and water vapor from the filament-forming material, a jacket, a feed screw for feeding the filament-forming material from said chamber to and through said jacket, said jacket and said feed screw being tapered whereby said feed screw has a higher rate of feed at the inlet to said jacket than at the outlet from said jacket to place the filament-forming material under pressure and eliminate voids therefrom, means for shifting the feed screw axially with respect to the jacket to adjust the clearance between the jacket and the feed screw, openings in the walls of said second tubular member and said tubular sleeve, means connecting said tubular sleeve to said feed screw whereby the rotation of the feed screw will bring said openings into alignment intermittently for permitting the filament-forming material to enter said chamber, means for disconnecting the vacuum applying means from said chamber when the openings are in alignment, means for heating the jacket to melt the filament-forming material, a gear pump for metering the molten filament-forming material, and a spinnerette for converking the molten filament-forming material from the gear pump into filamentary material.

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