Feb. 17, 1942. W. W. HECKERT 2,273,105

METHOD AND APPARATUS FOR THE PRODUCTION OF ARTIFICIAL STRUCTURES

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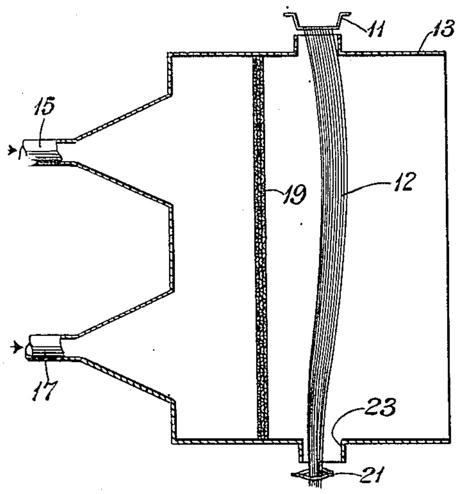


Fig. 1

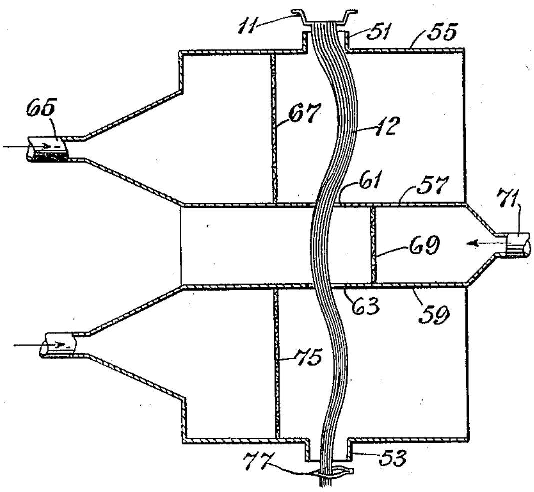


Fig. 3

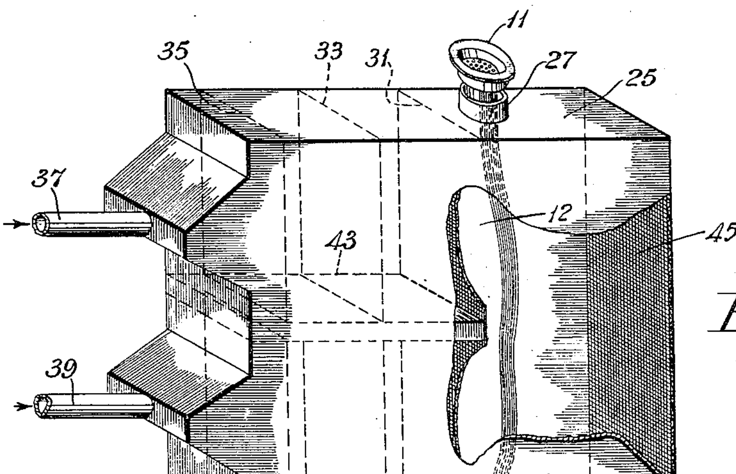
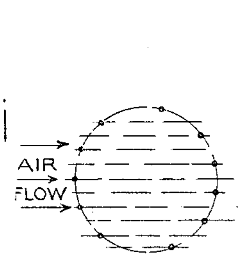
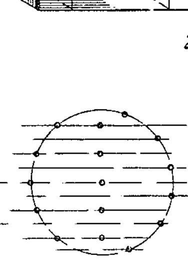


Fig. 2





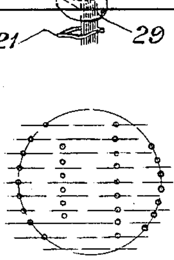


Fig. 4 Fig. 5 Fig. 6

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METHOD AND APPARATUS FOR THE PRODUCTION OF ARTIFICIAL STRUCTURES

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15 Claims. (Cl. 18—8)

This invention relates to the spinning of molten organic filament-forming compositions for the production of filaments, yarns, ribbons, and the like. More particularly it relates to an improved method and apparatus for the spinning of such molten compositions whereby to obtain spun structures having greater uniformity of physical and chemical characteristics.

Heretofore, in the spinning of molten organic filament-forming compositions it was difficult, if not impossible, to obtain yarns, filaments and like structures having a uniform denier throughout the length thereof. Such structures as have previously been formed from molten organic filament-forming compositions have also been found to be non-uniform as to dyeing characteristics, drawability, etc. It has now been discovered that when molten organic filament-forming compositions are passed through the atmosphere slight air drafts and the like somewhat affect the spinning operation, and it has furthermore been found that the movement of the filaments or yarns sets up a turbulent air movement which also objectionably affects the uniformity of physical characteristics of the resultant product.

It is, therefore, an object of this invention to provide an improved method and apparatus for the spinning of molten organic filament-forming compositions to produce spun structures having a constant denier and having uniform dyeing properties along the length thereof.

It is a further object of the present invention to provide an improved method and apparatus for the rapid and uniform cooling of the spun structures.

It is another object of this invention to provide an improved method and apparatus for the spinning, at high rates of speed, of molten organic filament-forming compositions to produce spun products having a uniform denier and having a high tenacity.

Other objects of the invention will appear hereinafter.

The objects of this invention are accomplished, in general, by spinning the molten organic filament-forming composition through a chamber in which air or other inert gas is passed with a straight-line flow across the path of the moving spun structures. This may be accomplished, for example, by providing along one side of the chamber a foraminous partition whereby to cause the gases to pass said partition prior to contact with the spun structures. The straight-line flow of the cooling medium must be maintained until it has passed the spun structures, and is preferably allowed to escape through the opposite side of said chamber. It is, furthermore, preferred that the straight-line air-flow contact the filaments substantially at right angles to the normal direction of flow of the spun structure.

The nature of the invention will be more clearly apparent by reference to the following detailed description when taken in connection with the accompanying illustration, in which:

Figure 1 is a diagrammatic side elevational view, with parts in section, showing a simple form of apparatus for conducting a straight-line air-flow across the path of the filaments in accordance with the present invention.

Figure 2 is a perspective view, with parts broken away, showing a modified form of cross-flow cooling chamber.

Figure 3 is a diagrammatic side elevational view of still another modification of apparatus for imparting a straight-line air-flow across the path of the spun structure.

Figures 4, 5 and 6 are diagrammatic illustrations of perforated spinnerets suitable for use with a cross-flow cooling chamber in accordance with the present invention.

Referring to Figure 1 of the drawings, reference numeral 11 designates a spinneret through which a molten organic filament-forming composition is extruded to form a bundle of filaments 12. The extruded filaments are permitted to pass a short distance through the atmosphere and are then passed through a chamber 13. The chamber 13 is provided with cooling air inlet means 15 and 17. A screen 19 is positioned between the air inlet means and the bundle of filaments passing through the chamber. The air as it passes through the chamber 13, therefore, must pass through the screen 19 just prior to contacting the bundle of filaments. The screen 19 will impart a substantially straight-line air-flow to the cooling medium until the latter has passed the bundle of filaments. A thread guide 21 may be positioned at the bottom of the chamber 13 so as to prevent the bundle of filaments from contacting the side walls of the chamber 13 adjacent opening 23.

Referring to Figure 2 of the drawing, the filaments passing from the spinneret 11 are passed through opening 27 of chamber 25, through the chamber 25 and out through the opening 29. A plurality of screens 31, 33 and 35 are positioned within the chamber 25 between the cooling medium inlet means 37 and 39 and the bundle of filaments 12. A partitioning means 43 is positioned perpendicularly to the screens 31, 33 and 35. In this form of apparatus the cooling medium passed through the chamber 25 may be given different velocities. For example, the velocity of the cooling medium flowing into chamber 25 through inlet means 37 may be less than the velocity flowing into said chamber through inlet means 39. The screens 31, 33 and 35 impart a straight-line motion to the cooling medium prior to the contact thereof with the bundle of filaments 12. The last screen 31 must be sufficiently near the bundle of filaments so that the straight-line motion imparted to the cooling medium will be maintained until the latter has passed the bundle of filaments. A screen 45 is positioned at the outlet side of the chamber 25. This screen may be provided to prevent drafts of air from entering the chamber 25 and breaking up the straight-line air-flow referred to.

Referring to Figure 3 of the drawing, the bundle of filaments 12 passing from the spinneret 11 is passed through the openings 51 and 53 of chamber 55. The chamber 55 is divided into three sections by means of partitions 57 and 59. These partitions contain openings 61 and 63 for the passage of the bundle of filaments. The uppermost section of chamber 55 is provided with air inlet means 65 and a screen 67, the screen 67 being positioned between the air inlet means 65 and the bundle of filaments 12. The cooling medium passed into the chamber towards the right as viewed in Figure 3 is given a straight-line motion by the screen 67, which straight-line motion will be maintained until the cooling medium has passed the bundle of filaments. The centrally located section lying between partitions 57 and 59 is provided with a screen 69 which lies between the air inlet means 71 and the bundle of filaments 12. The air will pass into this section on the right and flow towards the left as viewed in the drawing. A straight-line flow will be imparted to the air by means of screen 69. This straight-line flow of the air will be maintained until it passes the bundle of filaments 12. The lower section is substantially the same as the upper section, above described. This section is provided with air inlet means 73 and screen 75. The air passes from the left and flows towards the righthand side as viewed in the drawing. If desired, a thread guide 77 may be provided for the bundle of filaments to guide the same as they flow from the chamber outlet opening 53.

Referring to Figures 4, 5 and 6 of the drawing, three modified forms of spinneret means suitable for use in accordance with the present invention are disclosed. Figure 4 discloses a spinneret which will be positioned in the spinning apparatus in such a manner that the air-flow across the filaments will be in the manner illustrated in this figure. It is preferred that the openings, in accordance with this modification, be staggered relative to the air-flow so that each filament will be contacted by its own line of air-flow; that is to say, no filaments are closely positioned in a line with other filaments in the direction of the air-flow.

The modified form of spinneret illustrated in Figure 5 of the drawing is also characterized by this absence of a series of spinneret openings at the extreme outward points of the circle taken along a diameter perpendicular to the flow of the air. It will also be noted, in these modifications of the spinneret, that any two openings which are in line with each other in the direction of the air-flow are spaced sufficiently far from each other that there will be no interference between filaments.

In the modified form of spinneret shown in Figure 6 of the drawing, the spinneret openings are arranged along two arcs of a circle with the omission of openings along the two opposing sections of the spinneret adjacent the diameter perpendicular to the air-flow. Two lines of spinneret openings are arranged across the center of the said circle. The openings in these two lines are staggered relative to each other to prevent the positioning of any two spinneret openings in close proximity to each other and in a straight line with each other. Many other variations of spinneret may be employed; however, the three spinnerets illustrated in Figures 4, 5 and 6 are found to produce particularly desirable results in spinning by means of a straight-line air-flow in accordance with the present invention.

The following examples are given to illustrate specific details of the present invention, it being understood that the details as set forth in these examples are not to be considered limitative of the invention.

Example I

Polyhexamethylene adipamide having a melt viscosity of approximately 300 poises was fed through a feeding means into a nitrogen-filled chamber onto a melting grid maintained at about 285° C. The polymer melted and formed a pool beneath the grid from which it was pumped, by means of a metering pump delivering a substantially constant flow of polymer through a screen pack, and through a spinneret. The polymer was filtered by means of the screen pack which contained a large plurality of screens, for example, ten 16-mesh screens (16 meshes per inch), three 30-mesh screens, three 80-mesh screens, ten 150-mesh screens, one hundred twenty-five 200-mesh screens, and ten 325-mesh screens. The polymer was spun through a spinneret approximately one inch in diameter perforated with 20 holes located on a ⅝ inch diameter circle. The spinneret holes are substantially 0.006 inch in diameter. A cross-flow cooling chamber of the type illustrated in Figure 1 of the drawing is positioned at a distance approximately one inch below the face of the spinneret. A magnesium carbonate insulating ring is fastened between the spinneret and the cooling chamber to insulate the spinneret from said chamber. The length of the spinning chamber is approximately two feet and the thickness through the chamber is approximately three inches. Air is supplied to the spinning chamber at the rate of about 15 cubic feet per minute. The total denier of the yarn spun is approximately 175, and the spinning rate is approximately 1800 feet per minute. The yarn has a standard denier variation of one per cent and it emerges from the cooling chamber at a surface temperature of about 70° C. When drawn 410 per cent the yarn has a tenacity of 5.8 grams per denier and an elongation of 17 per cent.

The denier uniformity of the yarn was evaluated by cutting pairs of 9 cm. lengths of yarn from each of 25 successive meter lengths of yarn. The deniers calculated from the weight of these 9 cm. sections of yarn were averaged and a standard deviation calculated from the individual deviations. The standard deviation is the root mean square of the deviations from the mean. The standard deviation was divided by the average denier and expressed in per cent.

The standard deviation of 175-denier yarn spun at 1800 feet per minute, as pointed out above, was approximately one per cent. The standard deviation of 175-denier yarn spun at 900 feet per minute was 1.3 per cent. The yarn emerged with a surface temperature of 35° C. The yarn temperature was measured by means of a compensated thermocouple. Such yarn, when drawn 410 per cent, had a tenacity of 4.88 grams per denier and an elongation of 13 per cent.

When, in the above example, the cross-flow cooling chamber was removed and the yarn spun into the air without a cooling chamber of any sort, the standard deviation of the yarn varied erratically but generally fell between 3 and 4 per cent. When undrawn yarn, spun without the use of a cooling chamber, was knit into a fabric on a single end Wildman knitting machine, a fabric was obtained which gave very non-uniform dyeing, with bad streaks and bands running crosswise of the tubing. On the other hand, similar yarns spun through a cross-flow cooling chamber dyed very evenly and without noticeable streaks and bands. Denier and dyeing variations introduced during the spinning step also carry through to the drawn yarn.

Example II

Yarn of 150 denier and 15 filaments was spun at 3000 feet per minute in a manner very similar to that described in the preceding example. The cross-flow cooling chamber employed was made up of three sections; each section was fitted with a separate air inlet, two 100-mesh screens and a final 50-mesh screen. The upper section had a screen 8'' x 2.5'', the middle section was 12'' x 2.5'', and the lower section 12'' x 2.5''. The two inner screens were of 100-mesh whereas the screen through which the air was introduced into the spinning cell was a 50-mesh screen. By using separate sections it was possible to introduce varying amounts of air in the different sections. The following table tabulates the denier uniformities obtained at varying rates of air flow.

Distribution of air				Standard deviation	Spread of the deniers
Cu. ft./min. total	Cu. ft./min. per sq. in. upper 8''	Cu. ft./min. per sq. in. middle 12''	Cu. ft./min. per sq. in. lower 12''		
				Percent	*Percent*
18	0.3	0.2	0.2	1.58	6.5
19	0.24	0.24	0.24	2.22	9.6
32	0.53	0.36	0.36	1.06	4.7
42	0.52	0.52	0.52	1.18	4.1
46	0.77	0.37	0.51	1.05	4.0
60	1.0	0.67	0.67	1.54	6.2
70	1.17	0.78	0.78	1.33	5.2
70	1.17	0.78	0.78	1.65	7.7

Example III

A cross-flow cooling chamber was assembled from four sections similar to those described in the preceding example and assembled in such a manner that the air-flow in the upper 8-inch section was to the right, in the second 8-inch section the air-flow was to the left, in the third 12-inch section the air-flow was to the right, in the fourth 12-inch section the air-flow was to the left. A total of 35 cubic feet was blown into the chamber with a roughly equal distribution of air-flow between the sections. Yarn of 150 denier and 15 filaments was spun into the chamber at the rate of 3000 feet per minute. Under these conditions the standard deviation of the yarn was 1.43 per cent and the spread 5.8 per cent; in a second case it was 1.07 per cent and the spread 4.4 per cent. This arrangement had the advantage that the filaments were not bowed out to any substantial degree to one side, but followed a relatively straight course down the cooling chamber.

In the foregoing description the invention has been illustrated with specific reference to the spinning of polyhexamethylene adipamide, a synthetic linear polyamide but it is not so limited.

My invention has particular utility for the spinning of molten organic filament forming compositions which are crystalline in the solid state as evidenced by X-ray investigation. The synthetic linear polymer to which class the polyamides belong exhibit this property. Other types of synthetic linear polymers are polyesters, polyethers, polyacetals, mixed polyester-polyamides, etc. such as may be prepared by condensation reaction as described in U. S. Patent No. 2,071,250. Polymers prepared by the high pressure polymerization of ethylene which are more fully described in the copending application of Fawcett, Gibson and Perrin, Serial Number 123,722 filed February 2, 1937, now Patent No. 2,153,553, also are crystalline in the solid state.

The invention is also applicable to the spinning of other molten organic filament forming compositions such as the vinyl polymers, polystyrene and polyacrylic acid derivatives. Cellulose derivatives, e. g., cellulose acetate suitably plasticized can also be spun according to the invention.

The filament-forming material used in the process of this invention may contain modifying agents, for example, luster-modifying agents, plasticizers, pigments and dyes, anti-oxidants, resins, etc.

The cooling chamber is preferably supported in such a manner that the air-flow first intercepts the filament bundle between about one-half inch and two inches and preferably at about one inch from the face of the spinneret. If the spinneret is projected down into the cooling chamber, the high air-flow would probably cool it in an objectionable manner. On the other hand, if too much space intervenes between the face of the spinneret and the top of the cooling chamber, the filaments are blown to the leeward side of the inlet and accumulate on the edge of the opening to the cooling chamber. The inlet to the chamber is preferably an inch or more larger in diameter than the diameter of the spinneret.

The filaments should enter as close as possible to the screen which imparts the straight-line flow to the cooling medium. While these are the preferred conditions, it is of course true that it is possible to operate with the filaments entering as much as four or five inches or more from the screen and with the chamber lowered several inches or more below the face of the spinneret.

The cooling chamber shown in the illustration above described contains a plurality of air inlet means. The advantage of such a plurality of air inlet means lies in the fact that it is then possible to vary the amount of air introduced into the various sections of the chamber. If it is desired to vary the amount of air introduced into the various sections of the chamber it is desirable, if not necessary, to carry partitions in the cooling chamber between the various air inlet means on that side of the chamber from which the air-flow is towards the filament bundle. The partition should extend adjacent to the filament bundle.

Screens as heavy as 16-mesh and as fine as 100-mesh have been used in constructing cross-flow cooling chambers with about equal results, except that when 16-mesh screens are used it is preferred to use a number of layers of screens instead of one. Furthermore, the screen adjacent to the bundle of filaments preferably comprises a single layer of 50- to 100-mesh. Any number of layers of screen may be employed in the cooling chamber. At least one screen must be used so as to obtain non-turbulent, straight-line air-flow. The side walls of the cooling chamber (those parallel to the air-flow) should be as smooth as possible and should not deviate greatly from a position perpendicular to the screens. If they flare outward to a separation considerably larger at the outlet end of the cooling chamber, then the distribution of the air-flow across the outlet will be non-uniform. The velocity of the air-flow adjacent the side walls will have a lower velocity in comparison with the velocity of the air at the center of said outlet. This characteristic is undesirable and tends to oscillate the filament bundle from one side of the chamber to the other and may, under some circumstances, cause a variation in the denier of the yarn.

Although it is preferred, by reason of expediency, it is not essential to employ screens as a means for imparting a straight-line flow to the cooling medium. Other perforated elements or sections of glass wool, fabrics and the like may be used to advantage in place of screens.

Cross-flow cooling chambers such as shown in Figure 2 may be operated by means of a vacuum by replacing the single layer of screen 45 with a very fine screen or with a series of two or three screens separated by a short space, as for example, 200-mesh screens followed by a single 50-mesh screen on the inside. The screens, in this embodiment, function to prevent drafts within the spinning room from disturbing the straight-line air-flow.

The length and depth of the cooling chamber may also be varied greatly. Chambers as short as 24 inches and as long as 48 inches appear to operate successfully. If the chamber is shorter than about two feet, insufficient cooling of the filaments is obtained when spinning at high rates of speed such as, for example, 150-denier yarn at 3000 feet per minute. If the chamber, on the other hand, is made exceedingly long, for example four feet or greater in length, there is a tendency for the filaments to oscillate from one position to another, thus leading to poor denier control. A chamber length of 36 inches has been found to be quite satisfactory for spinning filaments of the usual deniers at rates as high as 1.25 grams of filament-forming composition per minute per hole in the spinneret. The depth of the cooling chamber (dimension perpendicular to the paper in Figure 1) is not at all critical except in so far as it is desirable to have it at least about an inch deeper than the diameter of the spinneret. The degree of cooling and the quality of denier control are a function of the volume of air-flow per unit of time per square inch of screen surface; consequently for reasons of economy of air-flow it is desirable to keep the cooling chamber as narrow as possible. A depth of 2.5 inches appears to be about the optimum depth for a chamber to be used with spinnerets having the holes distributed over a circle with a diameter of about 1⅛ inches. The volume of air-flow per unit of time per square inch of screen surface may also vary within comparatively wide limits, depending upon the speed of spinning and the denier and number of filaments being spun. Depending upon these conditions of spinning the air-flow is preferably made to vary between 0.2 and 2.0 cubic feet per minute per square inch of screen surface.

The cross-flow cooling chamber of the present invention imparts to the cooling medium substantially straight-line flow at right angles to the filaments. This produces the constant cooling of the filaments and thus prevents fluctuation in the point at which the filaments freeze after they pass through the spinneret openings. Constant cooling conditions also produce yarn with more constant drawing properties than would be possible if the cooling conditions varied from time to time. This undoubtedly produces an additional improvement in dyeing uniformity of the yarn, since small differences in drawing are known to cause large differences in depth of dyeing.

Straight-line air-flow generally persists for not more than 18 inches to two feet after the air emerges through a screen. The cross-flow cooling chambers of the present invention have a substantial advantage over all other types of cooling devices by reason of the fact that the filaments at no time pass more than a few inches away from the screens which impart a straight-line air-flow to the cooling medium. Under these conditions substantially straight-line air-flow exists about the filaments at all points within the cooling chamber. Furthermore, the cooling medium passing through the cross-flow cooling chamber of the present invention continually changes the air passing over the filament bundle. This results in better cooling.

Since it is obvious that many changes and modifications can be made in the method and apparatus hereinabove described without departing from the nature and spirit of the invention, it is to be understood that the invention is not to be limited except as set forth in the appended claims.

I claim:

1. In a process for the spinning of molten organic filament-forming compositions, the steps comprising spinning a continuous filamentous structure, passing said continuous structure through a cooling chamber, and passing a gaseous cooling medium with a substantially straight-line flow across the spun structure while the latter is being transformed from the molten to the solid state.

2. In a process for the spinning of molten organic filament-forming compositions, the steps comprising spinning a continuous filamentous structure, passing said continuous structure through a cooling chamber, and passing a gaseous cooling medium with a substantially straight-line flow across the spun structure while the latter is being transformed from the molten to the solid state, the flow of the cooling medium being substantially at a right angle to the normal passage of the spun structure.

3. In a process for the spinning of molten organic filament-forming compositions, the steps of extruding said molten composition to form a

continuous filamentous structure, passing said continuous structure through a cooling chamber, and passing a gaseous cooling medium with a substantially straight-line flow laterally across the extruded structure while the latter is being transformed from the molten to the solid state.

4. In a process for the spinning of molten organic filament-forming compositions, the steps of extruding said molten composition to form a continuous filamentous structure, passing said extruded molten composition for a short distance through the atmosphere, immediately thereafter passing said continuous structure through a cooling chamber, and passing a gaseous cooling medium with a substantially straight-line flow laterally across the extruded structure while the latter is being transformed from the molten to the solid state.

5. In a process for the spinning of molten organic filament-forming compositions, the steps of extruding said molten composition to form a continuous filamentous structure, passing said extruded molten composition for a distance of between about ½ and 2 inches through the atmosphere, immediately thereafter passing said continuous structure through a cooling chamber, and passing a gaseous cooling medium with a substantially straight-line flow laterally across the extruded structure while the latter is being transformed from the molten to the solid state.

6. In a process for the spinning of molten organic filament-forming compositions, the steps comprising spinning a continuous filamentous structure, passing said continuous structure through a cooling chamber, and passing a gaseous cooling medium with a substantially straight-line flow across the spun structure while the latter is being transformed from the molten to the solid state, the volume of the air-flow passed across said structure being from 0.2 to 2.0 cubic feet per minute per square inch.

7. In an apparatus for the spinning of molten organic filament-forming compositions, a spinneret having a plurality of orifices for forming continuous filaments from said molten composition, a chamber through which said filaments are passed, means for directing a cooling medium with a straight-line flow through said chamber across said filaments, no two orifices in said spinneret being in the same straight line in the direction of movement of said cooling medium.

8. In an apparatus for the spinning of molten organic filament-forming compositions, means for forming a continuous spun structure from said molten composition, a chamber positioned below said means, openings through the top and bottom of said chamber for the passage of said spun structure, inlet means, for a gaseous cooling medium, in a side wall of said chamber, and a plane member positioned in said chamber substantially parallel to said spun structure and between said inlet means and said spun structure, said member containing a plurality of openings to impart a straight-line flow to said gaseous cooling medium passing therethrough.

9. In an apparatus for the spinning of molten organic filament-forming compositions, means for forming a continuous spun structure from said molten composition, a chamber positioned below said means, openings through the top and bottom of said chamber for the passage of said spun structure, inlet means, for a gaseous cooling medium, in a side wall of said chamber, said inlet means connected to said chamber in a position normal to the direction of passage of said spun structure, and a plane member positioned in said chamber substantially parallel to said spun structure and between said inlet means and said spun structure, said member containing a plurality of openings to impart a straight-line flow to said gaseous cooling medium passing therethrough.

10. In an apparatus as defined in claim 8 in which said plane member comprises a perforated sheet.

11. In an apparatus as defined in claim 8 in which said plane member comprises a screen.

12. In an apparatus as defined in claim 8 in which said plane member comprises a plurality of screens.

13. In an apparatus for the spinning of molten organic filament-forming compositions, means for forming a continuous spun structure from said molten compositions, a chamber positioned below said means, openings through the top and bottom of said chamber for the passage of said spun structure, inlet means, for a gaseous cooling medium, in a side wall of said chamber, and a plane member positioned in said chamber substantially parallel to said spun structure and between said inlet means and said spun structure, a second plane member substantially parallel to the first plane member positioned on the opposite side of said spun structure, said plane members containing a plurality of openings to impart a straight-line flow to said gaseous cooling medium passing therethrough.

14. In an apparatus for the spinning of molten organic filament-forming compositions, means for forming a continuous spun structure from said molten composition, a chamber positioned below said means, openings through the top and bottom of said chamber for the passage of said spun structure, a plurality of inlet means, for a gaseous cooling medium, in the side wall of said chamber, and a plane member positioned in said chamber substantially parallel to said spun structure and between each of said inlet means and said spun structure, each of said members containing a plurality of openings to impart a straight-line flow to said gaseous cooling medium passing therethrough.

15. In an apparatus as defined in claim 14 in which the inlet means are positioned at opposite sides and at different elevations in the side wall of said chamber.

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