

Jan. 30, 1968

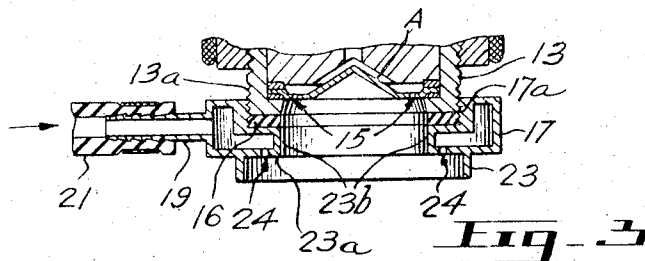
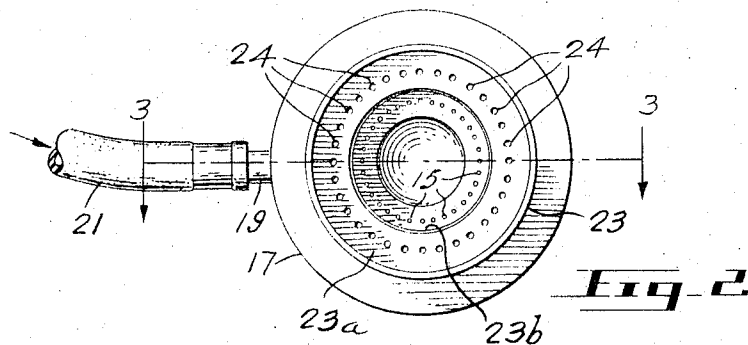
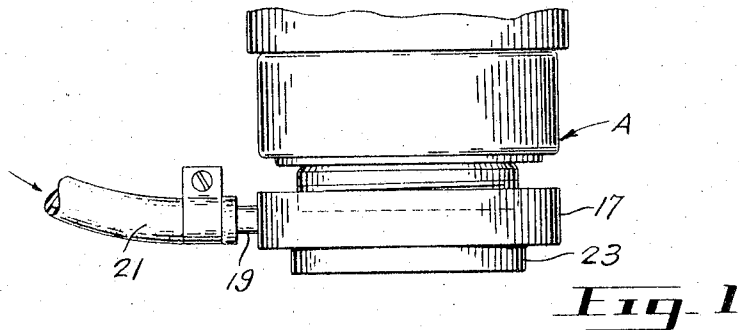
J. D. L. TESSIER

3,366,722

YARN MANUFACTURE

Filed Dec. 2, 1964

2 Sheets-Sheet 1



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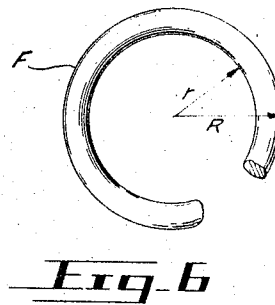
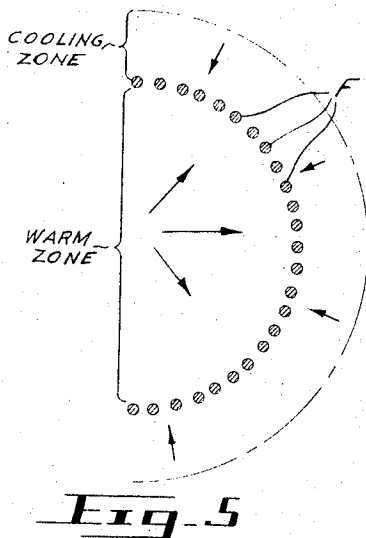
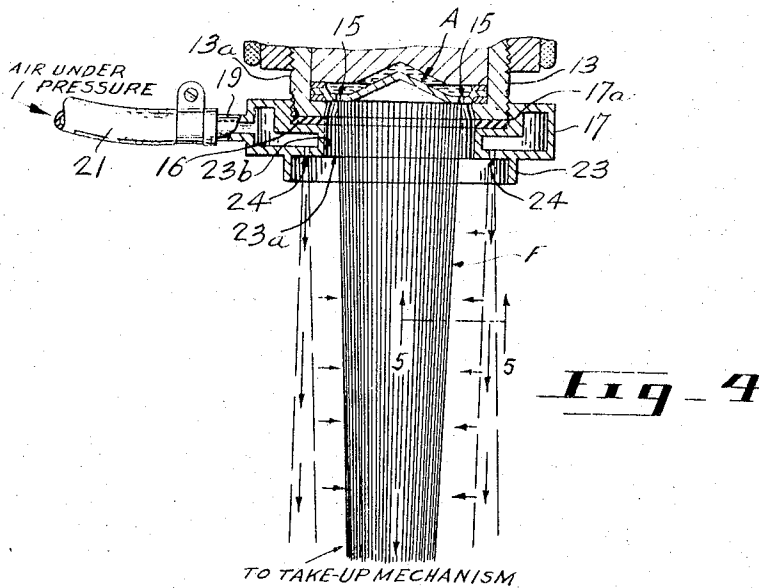
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YARN MANUFACTURE

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2 Sheets-Sheet 2



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YARN MANUFACTURE

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21 Claims. (Cl. 264-168)

This invention relates to the production of filaments and more particularly to thermoplastic filaments having a crimp making them suitable for use in bulked yarn.

Thermoplastic filaments have been produced by extruding them through a spinnerette and taking them up on a suitable take-up apparatus, the filaments being quenched by contact with air which impinges on them just after their formation. The art is crowded with various ways of providing the quenching air. The filaments are then gathered into so-called yarn and the filaments are oriented by drawing and annealed by relaxing them at an elevated temperature. When specific conditions are employed in this process with specific thermoplastic materials, bulked yarns having special characteristics are provided.

It is an aim of the present invention to provide for improved treatment of the yarns so as to result in a uniform crimp and an improved yarn made from the melt-extruded filaments. Broadly speaking, the applicant's process and apparatus is applicable in general to various thermoplastic materials and under various conditions. Again broadly speaking, according to the applicant's process, filaments are extruded from a thermoplastic polymer in the molten form through an orificed spinnerette having its spinning orifices arranged in a symmetrical pattern, preferably a circle and the filaments so formed are taken up to form yarn. Then, the filaments, shortly after they are formed, are cooled asymmetrically, that is to say on one side more than the other. In accordance with the invention, the cooling is uniform so that the asymmetric cooling pattern on each filament is substantially uniform. More specifically, in accordance with the invention, a curtain of air is formed in a pattern matching that of the spinning orifices and extending parallel to the filaments. Where the spinning orifices are arranged in a circle, the curtain of air is cylindrical and outwardly spaced from the circle of filaments, with the air initially substantially parallel to the filaments and evenly diffusing from the curtain in a symmetrical pattern to contact and cool each filament on its side adjacent to the cooling air. In this manner, an outside portion of each filament is uniformly cooled to a greater extent than an inside portion. Then, the filaments are oriented by drawing at a temperature below the softening point of the polymer and are subsequently relaxed at an elevated temperature so as to cause the filaments to coil.

The invention will be described more fully by reference to the accompanying drawings which show preferred embodiments and in which:

FIGURE 1 is a fragmentary side elevation of a melt-extruding head equipped with a cooling manifold in accordance with the invention.

FIGURE 2 is a bottom plan view of the head shown in FIGURE 1.

FIGURE 3 is a vertical cross-section along the line 3-3 of FIGURE 2.

FIGURE 4 is a vertical cross-section along the line 3-3 of FIGURE 2 introducing schematically the extruded filaments and the air curtain.

FIGURE 5 is a schematic illustration viewing the extruding head from below to show the relationship of the

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air curtain and other surrounding atmosphere to the filaments.

FIGURE 6 is a schematic view of a loop of fiber formed from a short length of a filament extruded, quenched and stretched according to the invention, then cut from the filament and heated to cause it to curl.

Referring more particularly to the drawings, A represents a spinnerette mounted on the end of an extrusion tube 13, for example as shown in copending United States patent applications owned by applicant's assignee, Ser. No. 371,174, filed May 25, 1964, and now U.S. Patent 3,238,592, Killoran (deceased) et al., and Ser. No. 347,595, filed Feb. 26, 1964, Killoran (deceased) et al. The jet is provided with a plurality of spinning orifices 15 arranged in a circle. Thermoplastic filament-forming material is molten as it encounters the jet A and passes through the orifices 15 to form a number of filaments F. The filaments pass down, as shown, to all intents and purposes in parallel relationship (although in actual fact they converge slightly) and substantially perpendicular to the face of the jet A. The filaments are then taken up on a take-up mechanism B. The jet is surrounded by an annular air manifold 17 whose cross-sectional shape is shown in FIGURE 1. The manifold has an intake nipple 19 connected to an air supply pipe 21. The manifold 17 has a downwardly extending cylindrical skirt 23 substantially concentric with the ring of openings 15 and a wall 23a extending inwardly from the skirt 23 parallel to the jet A terminating where it merges into an upwardly extending wall 23b substantially parallel to the direction of travel of the filaments. The wall 23a is provided with a ring of air openings 24 inside the skirt and spaced a given distance from the position the filaments F assume when the spinning operation is being carried out. The ring of air openings 24 is also concentric with the ring of spinning orifices 15. In the construction shown, the end of the extrusion tube 13 is externally threaded as at 13a. The manifold 17 is internally threaded as at 17a and thereby mounted on the end of the extrusion tube with a gasket 16 intervening the end of the extrusion tube 13 and a part of the manifold 17.

In operation, the molten filament-forming material is extruded through the openings 15 to form filaments F which are taken up by the take-up mechanism B at a greater speed than the average velocity of the molten material passing through the openings 15 so that the filaments F are attenuated. At the same time, air is supplied through the pipe 21 to the manifold 17 and passes out through the openings 24 to form a substantially continuous curtain of cooling air surrounding the filaments F. Since these filaments are arranged in a circle and are all substantially equidistant from the curtain of air, they all receive substantially the same cooling effect. The part of each filament closest to the air curtain is cooled relative to the other side of the filament farthest from the air curtain. This eccentric or asymmetric or unsymmetrical cooling effect results in the formation of a filament which, when subsequently stretched and heated, tends to curl, as will be more fully explained later. In other words, each filament has a differential birefringence across its width. Because the air is jetted substantially parallel to the filaments and because the curtain formed is substantially uniform all around as a cylinder, the air diffusion against the filaments is uniform, i.e. the filament-air curtain pattern is symmetrical and a very even cooling effect is produced, and consequently a substantially regular curl in the resulting filaments.

The dimensions of the apparatus may vary within certain limits and the following preferred limits are given by way of example—jet diameter preferably within the range from about one and one-quarter inches to about

two inches, spinning orifices in a single circle having from about a dozen to about one hundred and fifty orifices. The orifices are preferably circular and of equal diameter throughout their length and the respective orifices are preferably of equal size. Preferably the circle of orifices is set inwards from the margin of the jet from about one-eighth of an inch to about one-quarter of an inch. The thickness of the jet is preferably from about twenty thousandths of an inch to about one hundred thousandths of an inch, but this is not critical. The diameter of the orifices is preferably from about 0.005 to about 0.025 of an inch.

The air ring preferably has two circles of air holes, each having from about twenty to about two hundred holes. The diameter of the holes is preferably within the range from about 0.01 to about 0.03 inch in diameter, with the holes preferably equally spaced. The circles of holes are preferably spaced apart from about one-sixteenth of an inch to about one-quarter of an inch with the inner ring having a diameter within the range from about one and one-half inches to about two and one-half inches. If desired, one ring can be used instead of two and the ring or rings can be in the form of a slot instead of a set of holes.

The distance between the extrusion orifices and the inner ring of air holes is preferably from about one-sixteenth of an inch to about one inch, the axis of the air holes varying from a line parallel to the axis of the jet not more than about 20° inwards or outwards and is preferably substantially parallel to the axis of the jet. In the circumferential direction the air holes should direct the air substantially parallel to the filaments. The outlet of the cooling holes is preferably from about one-quarter of an inch to about one inch below the lower face of the spinnerette, desirably around one-half inch below.

In accordance with the invention, it is preferable that the take-up speed be less than about 200 linear feet per minute, with the curtain of air formed by the air jets having an effective length from approximately one-half inch to two and one-half inches below the spinnerette. To this end it has been found preferable to supply air to form the curtain at a rate of from about one to about three cubic feet per minute. The air leaving the feed holes can be at room temperature and need not be cooled, but must not be too warm to impair its quenching effect.

After quenching, the yarns are taken up and are then hot-stretched to orient the filaments and then relaxed at an elevated temperature. For polypropylene the stretching would be at not more than 130° C. and the relaxing at approximately 135° C.

VARIABLE FACTORS

Various heat extrudable polymers may be spun according to the invention. Particularly advantageous results can be achieved with isotactic polypropylene and a specific example will therefore be given of typical conditions used in preparing bulked yarn, from isotactic polypropylene filaments, according to the invention.

Preferred conditions for working with polypropylene are as follows. A typical spinnerette adapted to extrude filaments vertically downward has seventy-five spinning orifices of 0.012 inch in diameter in a single circle having a diameter of one and one-quarter inches. The number of holes can be varied between about a dozen and one hundred and fifty.

A standard air ring 17 for this purpose has an outer ring of thirty holes and an inner ring of ninety holes of 0.018 of an inch in diameter and all equally spaced. The two rings of holes are on the same plane and about one-sixteenth of an inch apart, the inner ring having a diameter of about two inches.

At a two pound per hour extrusion rate per jet, about two cubic feet per minute of air is supplied through the pipe 21. The temperature of the air leaving the feed holes 24 is about 75° C. A typical overall linear air speed

at the holes is of the order of ten thousand feet per minute. The cooling air holes 24 are three-quarters of an inch below the lower face of the spinnerette A and one-half an inch outside the ring of holes 15 on the horizontal plane.

Preferably, the air from the holes 24 is directed vertically downward. The extruding filaments deviate only a few degrees from the vertical as they form an elongated cone, so that the air curtain is substantially parallel to the filaments. The direction of projection of the air from the air holes should not vary from a line parallel to the axis of the jet more than about 20° in the radial direction inwards or outwards and should be substantially parallel to the axis of the jet in the circumferential direction.

Yarn take-up speeds of between sixty and two hundred feet per minute are effective. For one example, yarns of 3750 denier were spun at one hundred and twenty feet per minute and 90 grams tension. This corresponds to 24 mg. per denier. For this particular denier the applicant prefers a tension between about 70 and about 120, corresponding to about 19 to about 32 mg. per denier.

MEASUREMENT OF CRIMP

The crimp of a filament yarn has generally been expressed by two figures, namely the number of crimps per inch and the crimp amplitude or by some other set of two figures. One of the disadvantages of such a measurement is that the values obtained are too greatly dependent on fiber diameter and fiber tension. The finer fiber has a finer crimp and the larger fiber a lower or coarser crimp.

The helical or three dimensional crimp obtainable by the applicant's process is so pronounced that it is desirable to measure it by a more direct method. According to this method, the stretched fibers are chopped at a length of from five to fifty thousandths of an inch depending on the expected coil. The chopped fibers are then placed in an air oven at 135° C. for a period of five minutes. Upon heating, each fiber will form a highly regular loop, i.e. part of a circle essentially in one plane, as shown in FIGURE 6, which can be readily measured either by visual examination or through the medium of a photograph. In actual practice, there may be a slight departure from one plane as in the case of a piece cut from a coil spring. But, for all practical purposes of measurement, as described, the short loop as illustrated in FIGURE 6 may be considered as lying in one plane.

A measure is taken of the ratio R/r in which R is the radius of curvature of the outside of the loop and r is the radius of curvature of the inside of the same loop. A straight fiber would have a ratio of unity. According to the invention, it is possible for R/r to range from about 1.1 to about 1.5 and even in the unusually high crimp range of 1.3 to 1.5. Within the range of 1.1 to 1.5 there are generally from about 15 crimps to about 100 crimps per inch and at the higher ratio at the preferred or special ratio of 1.3 to 1.5 there are usually more than 30 crimps per inch. Operating according to this invention the regularity of the loops may be controlled so that the ratio R/r does not vary plus or minus more than about 0.05. The number of crimps per inch is within the range from about 30 to about 100.

The applicant has, for convenience, referred to the cooling gas as air since this is the most readily available and practical gas. However, other gases may be used within the spirit of the invention.

Preferred polymers for treatment according to the invention are isotactic polypropylene, poly acetal resins, poly-3-methylbutene and other poly alpha olefins, for example poly-4-methyl pentene and blends and copolymers. The principles of the invention are also more broadly applicable to other thermoplastic filament-forming synthetic resins.

Reference will now be made to the accompanying examples illustrating preferred processes using preferred

polymers, temperatures, etc., carried out according to this invention.

Example 1

Isotactic polypropylene resin of a melt index of 3.1 units was extruded as a 3700 denier, 75 filaments yarn. The yarn was cooled as it emerged from the spinnerette by a circular curtain of air controlled at a rate of 2 c.f.m. Yarn tension as measured between the spinnerette and the first guide was 90 grams or 24 mg./denier. This yarn was subsequently drawn by a factor of 3.8, this being the ratio of output to input linear speeds on the draw rolls. The yarn was fed in at an input speed of 25 feet per minute at drawing. After being drawn, yarn size was reduced to 1130 denier and the yarn crimped spontaneously and uniformly when subjected to heat at about 135° C.

A sample of the drawn yarn was cut to a length of 0.033 inch and heated in an air oven for a period of 10 minutes at 135° C. After this treatment, the curled fibers were photographed and the ratio R/r of the outer/inner radius was found to be of the order of 1.45.

Example 2

A yarn of 615 denier, 50 filaments, was extruded from a polypropylene "Pro-fax" of a 3.5 Melt Index as manufactured by Hercules Powder Company. Yarn was taken up at a speed of 190 feet per minute. The yarn was cooled using 0.5 c.f.m. of air at the spinnerette. Extrusion temperature as measured in the melt just before it entered the spinnerette was 271° C. Yarn tension between the spinnerette and the first guide was found to be 17 grams corresponding to 28 mg. per denier. The yarn was then drawn at a temperature of 70° C. by a ratio of 2.5, the actual draw on the yarn being about 2.1 as the yarn tends to shrink between the outlet roll and the take-up mechanism. The yarn was then cut into short fibers of 0.023 inch which were allowed to curl in an air oven at a temperature of 135° C. for a 10 minute period. After this treatment, the curled fibers were photographed and the ratio R/r was found to be of the order of 1.35.

I claim:

1. A method of melt extruding continuous filaments of a thermoplastic polymer, said filaments having substantially regular crimps, comprising:

extruding the filaments in a symmetrical pattern through a single orificed row spinnerette and forming a curtain of cooling gas travelling at high velocity in a zone adjacent the spinnerette, the curtain surrounding the group of extruded filaments from a level below the spinnerette and being spaced not more than one inch from the filaments, and extending substantially parallel thereto in a pattern symmetrical with the pattern of the filaments, the gas travelling in the same direction as the filaments, so that each filament is preferentially cooled on the side thereof adjacent to the cooling gas curtain, whereby a latent regular crimp is induced into each of the filaments.

2. A method as claimed in claim 1 wherein the curtain is formed at a level not more than one inch below the level of the spinnerette.

3. A method as claimed in claim 1 wherein the curtain of air is formed at a position between $\frac{1}{16}$ inch to 1 inch laterally from the filaments and between $\frac{1}{4}$ inch and 1 inch below the spinnerette.

4. A method as claimed in claim 2 wherein the filaments are extruded from a circle of orifices.

5. A method as claimed in claim 2 wherein the filaments are extruded from a circle of orifices, the diameter of the circle being not more than two inches.

6. A method as claimed in claim 1 including the steps, subsequent to cooling the filaments by means of said curtain of cooling gas, of drawing and relaxing the filaments at an elevated temperature to develop said latent crimp to produce coils in the filaments, thereby producing a bulked yarn.

7. A method as claimed in claim 6 wherein the curtain of air is formed at a position between $\frac{1}{16}$ inch to 1 inch laterally from the filaments and between $\frac{1}{4}$ inch and 1 inch below the spinnerette.

8. A method as claimed in claim 6 wherein the extruded filaments are taken up at the linear rate of less than 200 feet per minute and in which said curtain has an effective length of $\frac{1}{2}$ inch to $2\frac{1}{2}$ inches.

9. A method as claimed in claim 6 in which the filaments are formed in a group not exceeding 150 filaments.

10. A method as claimed in claim 6 in which the filaments are taken up at a speed of between 60 and 200 feet per minute.

11. A method as claimed in claim 6 wherein the amount of gas applied to form said curtain is from 1 to 3 cubic feet per minute.

12. A method as claimed in claim 6 in which said polymer is isotactic polypropylene.

13. A method of melt extruding continuous filaments of a thermoplastic polymer, said filaments having substantially regular crimps, comprising:

extruding the filaments in a symmetrical pattern through a single orificed row spinnerette and forming a curtain of cooling gas travelling at high velocity in a zone adjacent the spinnerette,

the curtain surrounding the group of extruded filaments from a level below the spinnerette and being spaced not more than one inch from the filaments,

and extending substantially parallel thereto in a pattern symmetrical with the pattern of the filaments,

the gas travelling in the same direction as the filaments, so that each filament is preferentially cooled on the side thereof adjacent to the cooling gas curtain, whereby a latent crimp is induced into each of the filaments,

stretching said filaments, subsequent to cooling of the filaments by means of said curtain of cooling gas, at an elevated temperature and relaxing said filaments to develop said latent crimp to produce coils in the filaments, providing bulked yarn, the filaments of which have a substantially uniform high helical crimp made up of a plurality of substantially regular loops in which the ratio R/r is within the range from about 1.1 to about 1.5, wherein R is the radius of curvature of the outside of the loop and r is the radius of curvature of the inside of the loop.

14. A method as claimed in claim 13 in which the ratio R/r is within the range of from about 1.3 to about 1.5.

15. Apparatus for melt extruding continuous filaments of a thermoplastic polymer, said filaments having substantially regular crimps, comprising:

a melt extruder having a spinnerette with orifices in a single row arranged in a symmetrical pattern together with means for supplying thermoplastic polymer to said spinnerette in a molten form and forcing it through the orifices in the form of filaments,

means for drawing and taking up said filaments, and gas projecting means disposed below the spinnerette

and having orifice means directed for forming a curtain of cooling gas travelling in the same direction as the filaments at high velocity in a zone adjacent the spinnerette and shaped such as the curtain is of a symmetrical pattern surrounding the group of filaments and conforming to the pattern of the spinnerette orifices,

the curtain extending substantially parallel to the filaments in space not more than one inch therefrom and serving to cool the filaments preferentially on the side thereof adjacent to the cooling gas so as to induce a latent regular crimp in each of the filaments.

16. Apparatus as claimed in claim 15 wherein said gas projecting means is disposed not more than one inch below said spinnerette.

17. Apparatus as claimed in claim 15 wherein said gas projecting means is spaced between $\frac{1}{16}$ and 1 inch lateral-

ly from said filaments and between $\frac{1}{4}$ inch and 1 inch below the level of said spinnerette.

18. Apparatus as claimed in claim 15 wherein said spinnerette orifices are arranged in a circle and wherein said gas projecting means includes a manifold mounted to said extruder and surrounding said spinnerette, said manifold having downwardly directed gas discharge orifices arranged in a circle concentric with the circle of the spinnerette orifices, the apparatus also including means for supplying said manifold with cooling gas.

19. Apparatus as claimed in claim 15 further including means for stretching said filaments subsequent to cooling of the filaments by means of said curtain of cooling gas at an elevated temperature and for relaxing said filaments to develop said latent crimp to produce coils in the filaments providing bulked yarn.

20. Apparatus as claimed in claim 19 wherein said spinnerette has a diameter of from $1\frac{1}{4}$ inches to 2 inches and is provided with from 12 to 150 equally sized spinning orifices arranged in a circle, said orifices being circular and being of equal diameter throughout their length within the range from 0.005 to 0.25 inch, the circle of orifices being set inward from the margin of the spinnerette by a distance of from $\frac{1}{8}$ to $\frac{1}{4}$ inch, said manifold being provided with at least one circle of holes through which gas escapes from the manifold, the holes in the gas manifold having a diameter within the range of from 0.01 inch to 0.03 inch and there being 20 to 200 holes in each circle of air holes in the manifold, the radial distance between the extrusion orifices and gas holes being within the range from about $\frac{1}{16}$ inch to about 1 inch, the axis of the gas holes not varying from a line parallel to the axis of the jet more than about 20° in the radial direction inwards or outwards and being substantially parallel to the axis of the spinnerette in the circumferential direction, the outlet of the gas holes being from $\frac{1}{4}$ inch to 1 inch below the lower surface of the spinnerette, and cooling gas being supplied to the manifold at a rate effective to produce a curtain of gas issuing from the holes which curtain has an effective length from approximately $\frac{1}{2}$ inch to $2\frac{1}{2}$ inches below the spinnerette.

21. Apparatus as claimed in claim 19 wherein two

circles of holes are provided in said manifold, the circles of holes of said manifold being concentric and the inner circle having a diameter within the range from $1\frac{1}{2}$ inches to $2\frac{1}{2}$ inches and the circles being spaced apart by a distance of $\frac{1}{16}$ inch to about $\frac{1}{4}$ inch.

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