PROCESS AND APPARATUS FOR QUENCHING MELT SPUN FILAMENTS

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FIG. 2

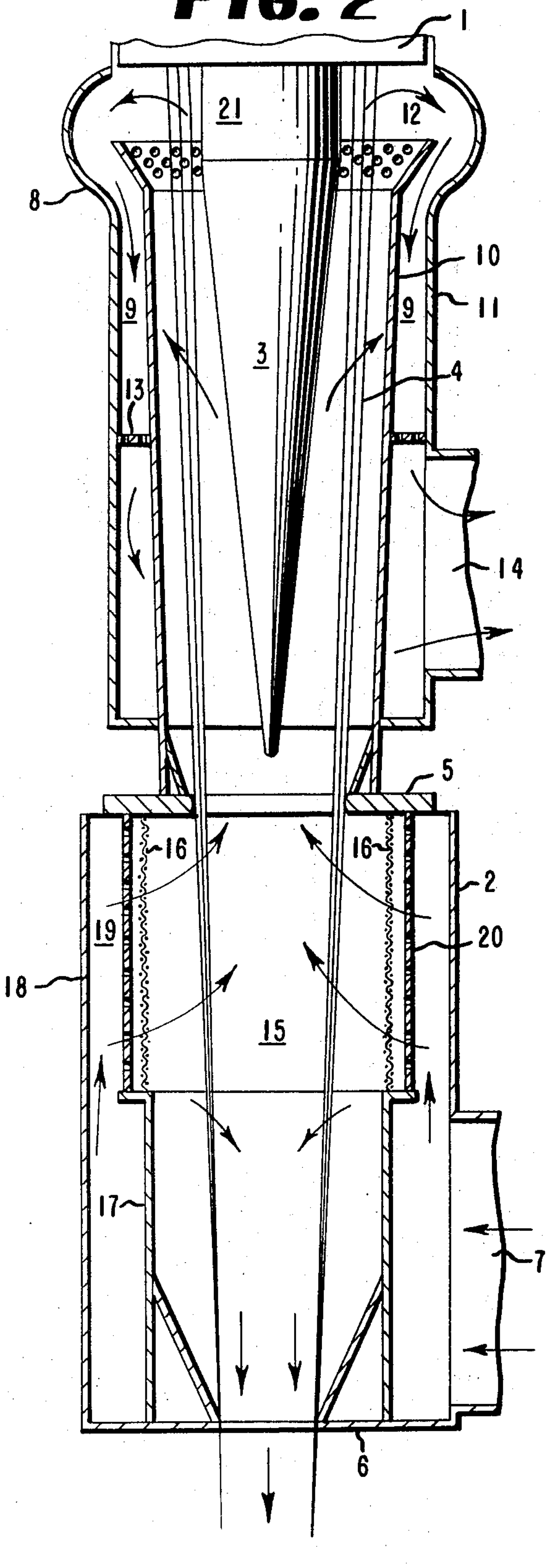

FIG. 1

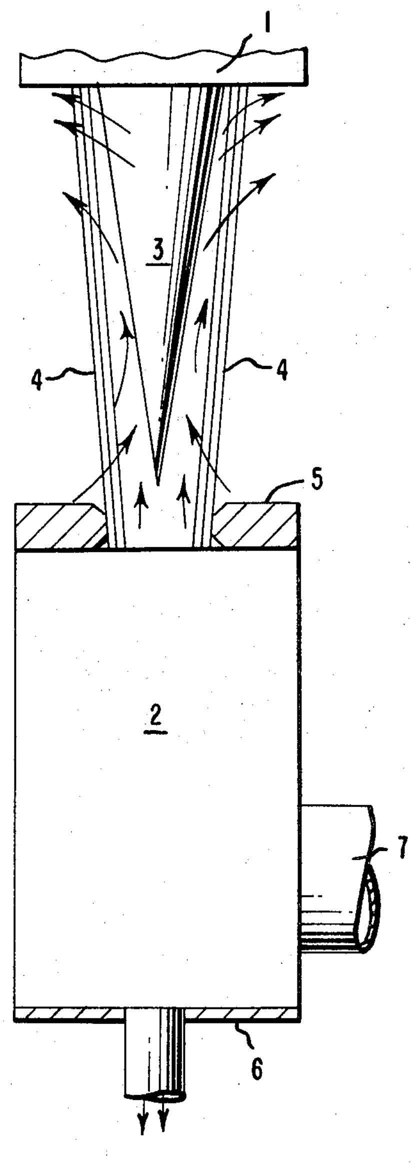

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FIG. 3

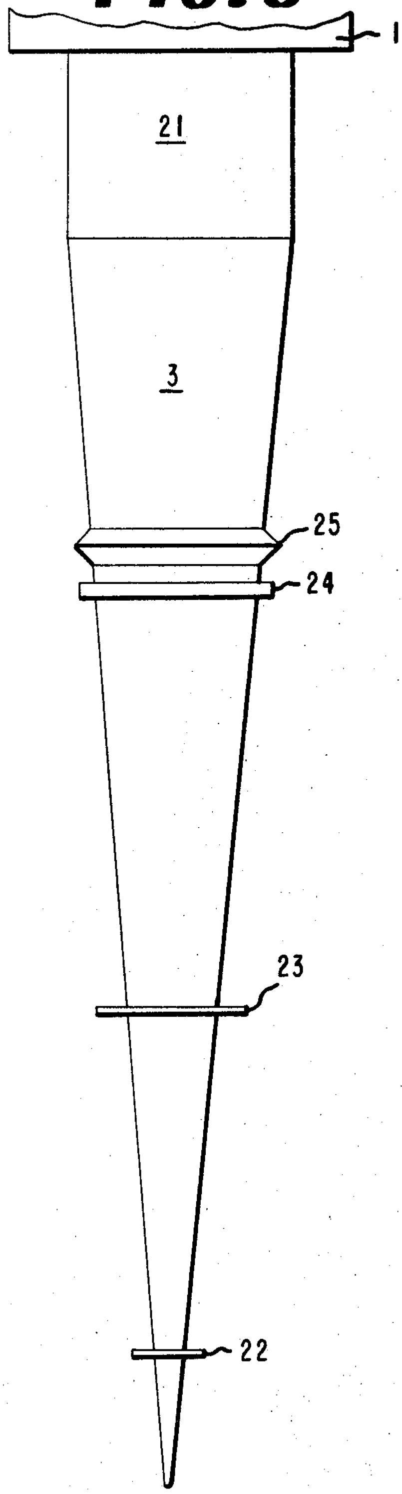


FIG. 4

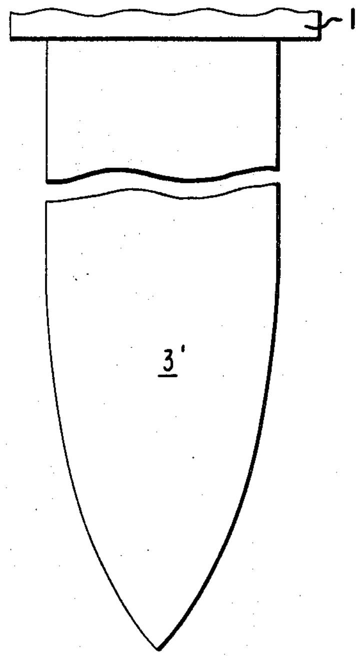
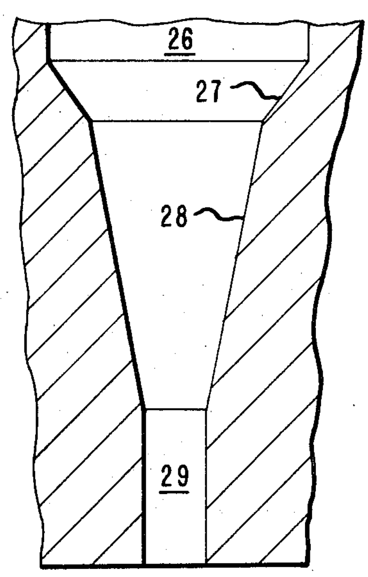


FIG. 5



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PROCESS AND APPARATUS FOR QUENCHING MELT SPUN FILAMENTS

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ABSTRACT OF THE DISCLOSURE

An improved radial quench process for filaments being extruded in the form of hollow bundles wherein the radial chimney is spaced from the spinneret and a tapered deflector extends from the spinneret downwardly in the hollow part of the bundle terminating above the chimney. Gas flow restrictors at each end of the chimney are sized to direct a portion of the inwardly flowing quench gas up the hollow part of the bundle toward the deflector which, in turn, directs the gas flow outwardly through the bundle.

BACKGROUND OF THE INVENTION

The invention relates to an improved quenching process and apparatus for melt spinning filaments from synthetic polymers.

In the production of polymeric filaments by melt spinning, the polymer is extruded from orifices provided in a spinneret plate, the molten streams of polymer are cooled to solidify them and the filaments so formed are forwarded to subsequent operations such as drawing. While many methods can be used to cool or quench the freshly extruded filaments, the most common involves contacting the filaments with cooled or room temperature air in the vicinity of the spinneret plate.

The processes described in the prior art to provide uniform quenching in multifilament spinning operations appear to fall into two general catagories, (a) cross-flow quenching where the quench air is blown across the path of the molten polymer streams and (b) radial quenching in which air is directed radially inward against the molten filaments and thereafter flows concurrently with the filaments as they travel downward. In a variation of the radial quenching process, a porous cylinder connected to an air supply has been positioned in the center of an array of filaments emanating from a spinneret to direct air radially outward against the filaments.

It is generally recognized by those skilled in the art that the quenching operation is among the most critical in a melt spinning process, since nonuniformities in the filaments due to the quench carry through the subsequent processing steps. Thus, nonuniform quenching may give rise to a migration of the solidification point which produces fluctuations in the diameter and in the orientation of the filaments. It has been found that filament yarns having large diameter variations (both across the bundle and along the length of the filament) are subject to more frequent breaks during drawing operations which, in turn, leads to poor productivity.

Quenching problems are magnified when attempts are made to increase the productivity of spinning positions by increasing the number of filaments and/or the throughput per spinning orifice. Both with cross-flow and radial quenching, it becomes more difficult to obtain uniform quenching across multiple rows of filaments, filaments which are closest to the source of quench air being cooled more rapidly than those further away. While it would be theoretically possible to increase the rate of heat removal

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and the quenching uniformity by increasing the turbulence of the quenching air flow, this is not an acceptable solution because it leads to an unstable threadline in which the filaments are moved around and may adhere to one another while still in the molten state. Supplying quench air inside a spinning threadline either requires expensive high pressure quench air for small pipes which can easily penetrate the bundle or causes problems with arranging the threadline around large pipes supplying air at low pressure.

The present invention provides an improved melt spinning process and apparatus and involves the use of a radial quench apparatus in a novel manner to increase the operating throughput of a melt spinning position without attendant losses in spinning continuity and filament uniformity.

SUMMARY OF THE INVENTION

The melt spinning process of the invention includes the steps of melting and extruding a synthetic organic polymer through a spinneret having spinning orifices arranged in a generally circular pattern and passing the streams of polymer downward through a filament guide means located a distance below a spinneret to form a hollow bundle of filaments, in which the filaments are uniformly distributed around the periphery. The improvement comprises passing a flow of quench gas radially inwards through the filaments at a point below the guide means, directing a portion of the quench gas upward through the center of said filament bundle and redirecting said portion of the gas to flow radially outward through the filaments, the total flow of quench gas and the portion directed upwards being chosen such that the filaments are in a substantially nontacky state when they pass through said guide means.

The apparatus of the invention includes as its major components a spinneret, a gas flow deflector and a radial quench flow device. The spinneret has spinning orifices arranged in a generally circular pattern for extruding molten synthetic filaments and the gas flow deflector preferably conical shaped with its vertex pointing downward, extends a distance from the spinneret along its central axis and has a diameter at its base smaller than the diameter of the circularly arranged spinning orifices. The quench device comprises a hollow cylindrical quenching chamber for directing a flow of quench gas radially inward against the filaments. The chamber is in axial alignment with the gas flow deflector and has its top end in the vicinity of the bottom end of said deflector. Gas flow restrictors positioned at the upper and lower ends of the quench chamber partially seal the ends against the filaments and are sized so that more than 50% of the quench gas exits through the top end of said chamber. The upper flow restrictor also acts as a guide to provide convergence of the filaments into a hollow bundle.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic elevation, partially in section showing one form of apparatus useful in the process of this invention.

FIG. 2 is a cross-sectional view showing a preferred embodiment of the apparatus of this invention.

FIGS. 3 and 4 represent different flow deflectors which can be used in the apparatus of this invention.

FIG. 5 shows a cross section through a spinneret orifice which may be used to spin high molecular weight polypropylene at high throughputs.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

In their preferred embodiment, the apparatus and process of this invention are used in the melt spinning of high molecular weight isotactic polypropylene. However, these may be used beneficially in the production of filaments from other melt spinnable polymers such as polyesters and polyamides.

FIG. 1 shows a schematic arrangement of an apparatus which may be used to carry out the process of this invention, which comprises a spinneret plate 1, a radial quench device 2, an inverted cone air deflector 3 attached to the spinneret plate, a flow restrictor 5 placed at the top end of the quench apparatus and a flow restrictor 6 placed at the bottom end. These flow restrictors are in the form of plates placed at the top and bottom of the quench apparatus with circular openings formed therein which may be lined with a ceramic or other suitable material to form a guiding surface for the filaments 4. Filaments 4 are partially converged into a hollow filament bundle by passage in contact with the guide surfaces of flow restrictor 5. The openings at the top and bottom of the quench are sized such that the major resistance to flow occurs at the bottom end of the quench device, thereby forcing a major part of the quench air through the upper end of the quench apparatus. Quench air is admitted via inlet conduit 7 and distributed as hereinafter described so that it is directed radially inward against the filament threadline entering the quench chamber, thereafter the flow restrictors 5, 6 cause a major portion of the air to emerge from the upper end of the quench chamber 2 and to flow upward for a short period of time through the center of the hollow bundle of filaments 4. The air then meets the conical flow deflector 3 and is redirected radially outward through the threadline. The length of the conical flow reflector and the quench air flow rates to be used are dependent on many factors such as the number of filaments, throughput per hole, spinning temperature, etc. Conical flow deflectors having a length of from about 10 to 25 inches have been found useful. Particularly suitable air flow rates are those which give a horizontal radial outflow component of velocity of about 10 to 12 feet per second, about 1 inch down below the spinneret, the total flow of air being such that about 70% goes out through the top end of the quenching apparatus.

Referring now to FIG. 2, the apparatus is seen to comprise spinneret plate 1, radial quench apparatus 2, a conical inverted flow director 3, top and bottom flow restrictors 5 and 6, respectively, and smoke removal apparatus 8 and the quench apparatus 2 are sealed against one another and against the spinneret to form a substantially air tight chamber around filaments 4.

The smoke removal device 8 has been found necessary in the melt spinning of polypropylene containing certain stabilising additives which tend to sublime or decompose at the spinning temperature forming fumes at the spinneret face. Smoke removal device 8 also assists in controlling the relative amounts of air going out through the top and bottom of the quench apparatus. The device consists of an annular exhaust chamber 9 formed between inner and outer wall members 10 and 11, respectively. Located at the top of inner wall member 10 is a funnel-shaped, perforated deflector 12. The purpose of this is to trap the filaments at startup and direct them through the inner wall 10. The perforations allow some air to flow through thus reducing the velocity over the deflector. Outer wall member 11 is shaped as shown to form a flared smoke diverting ring in the vicinity of the spinneret where the filaments are still molten and where a highly turbulent air flow would break them. This arrangement provides an open area for air flow over the funnel-shaped deflector 12 and allows the air to change directions smoothly thus providing low turbulence in the spinning zone. Conduit 14 is connected to a source of suction (not shown) and perforated baffle 13 provides symmetrical distribution of the suction in exhaust chamber 9 to provide uniform flow at the spinneret.

After passage through the smoke removal device, the filaments are passed down through a quenching chamber

generally designated by numeral 15. The walls of this chamber are formed from a cylindrical foraminous member 16 which is formed from a number of layers of fine mesh screen (e.g., 100 mesh screen). The foraminous member 16 and an exit tube 17 are mounted within generally cylindrical jacket 18 which is inwardly flanged at top and bottom to form an annular plenum chamber 19. Screen member 16 is surrounded by a perforated, cylindrical element 20 which assists in the distribution of air to the screens. Plenum chamber 19 is supplied with air or other cooling gas at a pressure slightly above atmospheric to provide a uniform radial flow of cooling gas into the quenching chamber through the foraminous member. Gas for the plenum 19 is supplied through inlet 7.

Upper and lower seals 5 and 6, respectively, are provided at the ends of the quench apparatus. In this embodiment, the inner surfaces of the seals which also act as filament guides and the outer radius of the filaments at the spinneret lie on one straight line. By partially sealing the lower end of the quench apparatus, most of the air is forced upwards through the top and is then redirected outward through the filaments by the conical flow deflector 3 to provide uniform and efficient quenching of the filaments in the vicinity of the spinneret. As shown, the conical deflector may be attached to the spinneret via a cylindrical spacer 21.

FIG. 3 shows a modified conical flow director 3, attached via spacer 21 to spinneret plate 1, having discs 22, 23, 24 and 25 attached thereon at various points along the length. These circumferential protuberances cause a greater portion of the quench air to be deflected into the bundle at points successively distant from the spinneret, thus, changing the air flow distribution.

FIG. 4 shows a bullet-nosed cylindrical flow deflector 3′ which can be used in the process and apparatus of this invention.

FIG. 5 represents a cross-section through a spinning capillary which is particularly suitable for spinning high molecular weight polypropylene at high throughputs. The capillary geometry comprises a counterbore 26 having a diameter of 0.0625″, a first taper 27 with an included angle of 60° x 0.023 inch long and a second taper 28 with an included angle of 20° x 0.069 inch long which terminates in a cylindrical capillary 29 of length 0.045 inch and diameter 0.015 inch.

In the examples, the diameter uniformity of the yarn is characterized as percent coefficient of variation (percent CV) which is measured as follows:

A yarn sample is embedded in an epoxy resin, microtomed to expose the fiber cross sections and photomicrographs at 150–200× magnification are taken. The diameter of a representative number of fibers is measured using a draftman's template having circles of different diameters and the percent CV can be computed from the following:

$$\text{Percent CV} = \frac{\text{Standard deviation}}{\text{Arithmetic mean of diameters}} \times 100$$

where

$$\text{Standard deviation} = \sqrt{\frac{\epsilon(Xi)^2 - \frac{(\epsilon Xi)^2}{N}}{N-1}}$$

where

Xi=individual diameter values
N=number of fibers measured

$$\text{Arithmetic mean} = \epsilon Xi/N$$

EXAMPLE I

Isotactic polypropylene having a Melt Flow Rate* (MFR) of 2.5 was melt-spun at 240° C. through a spinneret containing 200 orifices of the geometry shown in

*ASTM-D 1238-62-T at 230° C. and a load of 2160 gms.

FIG. 5, the orifices being arranged in five concentric circles containing, respectively, 25, 50, 50, 50 and 25 orifices each. The quenching arrangement was similar to that shown in FIG. 1 with the top flow restrictor **5** located 16 inches below the face of the spinneret and using a 17" long conical deflector having a 4" diameter base suspended from the spinneret face. The polymer was spun at a throughput of 2.5 gms./min./hole and quenched with 240 c.f.m. of 16° C. air, the relative sizes of the upper and lower flow restrictors being such that about 75% of the air exited through the top of the quench apparatus.

Spun fiber samples were collected at 662 y.p.p.m. and cross-sectional photomicrographs of 80 fibers selected at random showed a fiber diameter uniformity of 5.7% CV. Attempts to repeat the experiment without the conical flow deflector showed that air turbulence at the spinneret face caused the filaments to fuse.

EXAMPLE II

Spinning tests were run using the apparatus generally depicted in FIG. 2 using an isotactic polypropylene polymer of 3.2 MFR. The spinneret used contained 500 orifices of the type shown in FIG. 5 arranged in five circles of 100 orifices each. Throughput per hole was kept constant at 1.36 gm./min./hole and the spinning temperature used was 270° C. Flow deflector **3** had an over-all length of 17 inches and consisted of ½-inch long cylindrical base of 4 inch diameter transitioning to a right circular cone having a 4 inch diameter base and a 15 inch radius tip made from smooth aluminum. The deflector was connected to the spinneret via a 4 inch diameter 2 inch long spacer made from an insulating material to reduce heat losses from the spinneret.

After quenching, the filaments passed over feed rolls operating at a temperature of about 130° C. and a speed of about 300 y.p.m. and then over unheated draw rolls operating at about 900 y.p.m. Good spinning continuity was obtained when 180–200 c.f.m. of quench air were admitted at duct **7** and 110–130 c.f.m. removed at duct **14** (FIG. 2). Under these conditions, the coefficient of variation of undrawn filament diameter was less than 10%.

EXAMPLE III

Polypropylene of about 2.5 MFR was melt spun at 270° C. using the apparatus of FIG. 1 with a spinneret containing 100 orifices of the geometry shown in FIG. 5 arranged in a single ring. Quench air at a flow rate of 240 c.f.m. was introduced into the radial quench apparatus and 60–70% of this air emerged through the top. Spun yarn was collected at 420 y.p.m. at different throughputs/hole and the diameter uniformity was measured. The results given in Table I indicate that the process and apparatus of this invention permit spinning at higher throughputs without losses in filament uniformity.

TABLE I

Throughput, gm./min./hole:	Apparatus of FIG. 1 filament diameter percent CV
1.67	13.4
2.50	10.5
3.34	11.0

EXAMPLE IV

Polypropylene of about 2.5 MFR was melt-spun at 250° C. using the apparatus of FIG. 1 with the 500 orifice spinneret of Example II. The throughput/hole used was 1.37 gm./min. with a quench air flow rate of 255 c.f.m. of which 60–70% emerged through the top of the quench apparatus. The quenched filaments passed over a set of feed rolls operating at 315 y.p.m. and heated to about 130° C. and then over drawn rolls at 850 y.p.m. Operability was good with no break in the filament line occurring over the test period of 18 hours. A sample of undrawn yarn showed 8.5% CV of filament diameter. The drawn yarn had a tenacity of about 4 g./denier and about 18 denier/filament.

EXAMPLE V

Polypropylene of about 3.5 MFR was melt spun at 270° C. using the arrangement of FIG. 2 with a 1200 orifice spinneret in which the orifices were arranged in 6 rings of 150 and four inside rings of 75 orifices each. The throughput/hole was 0.57 gm./min. and a quench rate of 250–300 c.f.m. was used. The filaments were passed over heated feed rolls operating at 300 y.p.m. and drawn 2.0× to give final filament properties of about 10 denier/filament and 4.0 grams/denier.

With this increased number of filaments, good operability was obtained by modifying the conical deflector as shown in FIG. 3 to reduce the horizontal air flow component at the spinneret face. The dimensions of the air deflecting discs and their distance from the cone vertex are given in Table II, the conical deflector was otherwise the same as that described in Example II. Acceptable operability was also obtained when the modified cone was replaced by a 3.25 inch diameter 9 inch long bullet nosed cylinder of the type shown in FIG. 4.

TABLE II

	Outside diameter, inch	Thickness, inch	Distance from cone vertex
Disc Number:			
22	1⅛	1/16	2½
23	2¼	3/16	7
24	2 13/16	5/64	12½
25	2¼	¼	13

What is claimed is:

1. In a melt spinning process that includes the steps of extruding molten polymer through a spinneret having orifices arranged in a pattern to form a hollow bundle of filaments and passing a flow of quenching gas across the bundle to cool the filaments, the improvement comprising the steps of: passing said flow radially inwardly toward the center of said hollow bundle starting from an annular area spaced downstream from the spinneret; directing a portion of said flow upwardly through the hollow part of said bundle while avoiding substantial flow out of the bundle; and deflecting said portion outwardly through the filament bundle near the spinneret.

2. The process as defined in claim **1**, said portion being greater than 50% of the radial inward flow.

3. The process as defined in claim **2**, said portion being about 60% to 75% of the radial inward flow.

4. In a melt spinning apparatus including a spinneret for forming a hollow bundle of filaments, a cylindrical quenching chamber positioned below said spinneret said chamber having upper and lower ends through which said filaments pass and a means for supplying a quenching gas to the chamber, the improvement comprising: the upper end of said chamber being spaced downwardly from said spinneret, a deflector within said bundle extending downwardly from said spinneret and having a cross-sectional area diminishing toward said chamber, said deflector terminating above said chamber; and upper and lower gas flow restrictors positioned adjacent the upper and lower ends of the quench chamber, said upper and lower flow restrictors causing a portion of said quenching gas to flow upward and out the upper end of the chamber, the upper flow restrictor serving as a guide to provide convergence of the filaments into a hollow bundle and serving to keep substantially all of the upward gas flow within the hollow bundle.

5. The apparatus of claim **4**, said deflector being cone-shaped.

6. The apparatus as defined in claim **5**, said deflector having a plurality of protuberances spaced along its length.

7. The apparatus of claim **6**, said protuberances spaced being circumferential.

8. The apparatus as defined in claim **4**, including means positioned between said spinneret and said chamber for exhausting gas moving outwardly through said bundle.

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U.S. Cl. X.R.

264—237; 425—72