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(54) METHOD FOR COOLING AND FINISHING MELT-SPUN FILAMENTS

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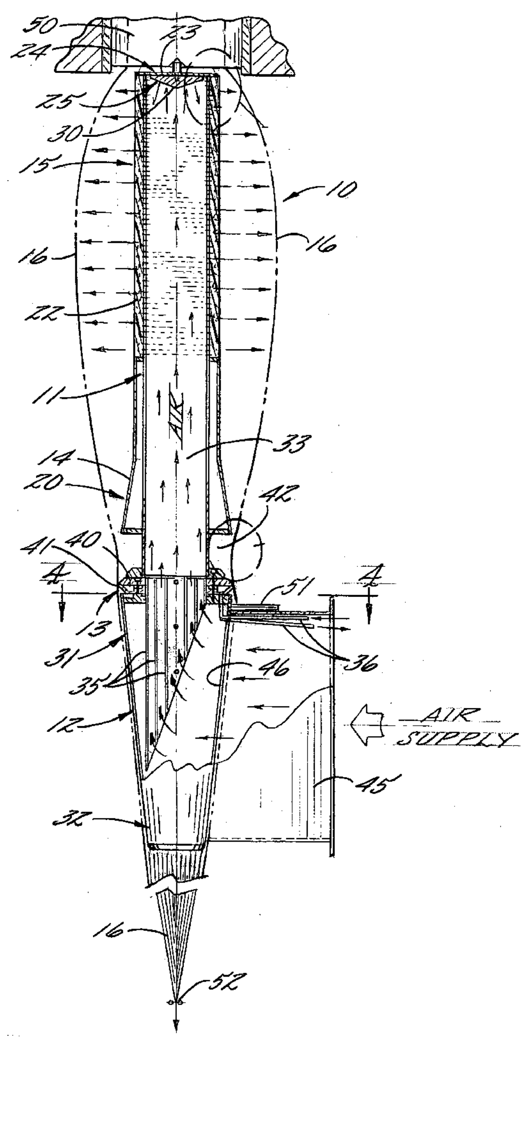
(52) U.S. Cl. **264/130**; 264/211.14

(57) **ABSTRACT**

A hollow quench stick tube capable of cooling and finishing melt-spun filaments comprises in one embodiment a hollow cooling tube connected to a hollow support tube, a finish applicator that substantially surrounds the hollow support tube, and a spoiler skirt that substantially surrounds the hollow cooling tube and that is spaced apart from the finish applicator to define a spoiler void. In operation, the spoiler skirt diverts a flow of air to create a partial vacuum in the spoiler void that draws a filament stream inwardly against the finish applicator.



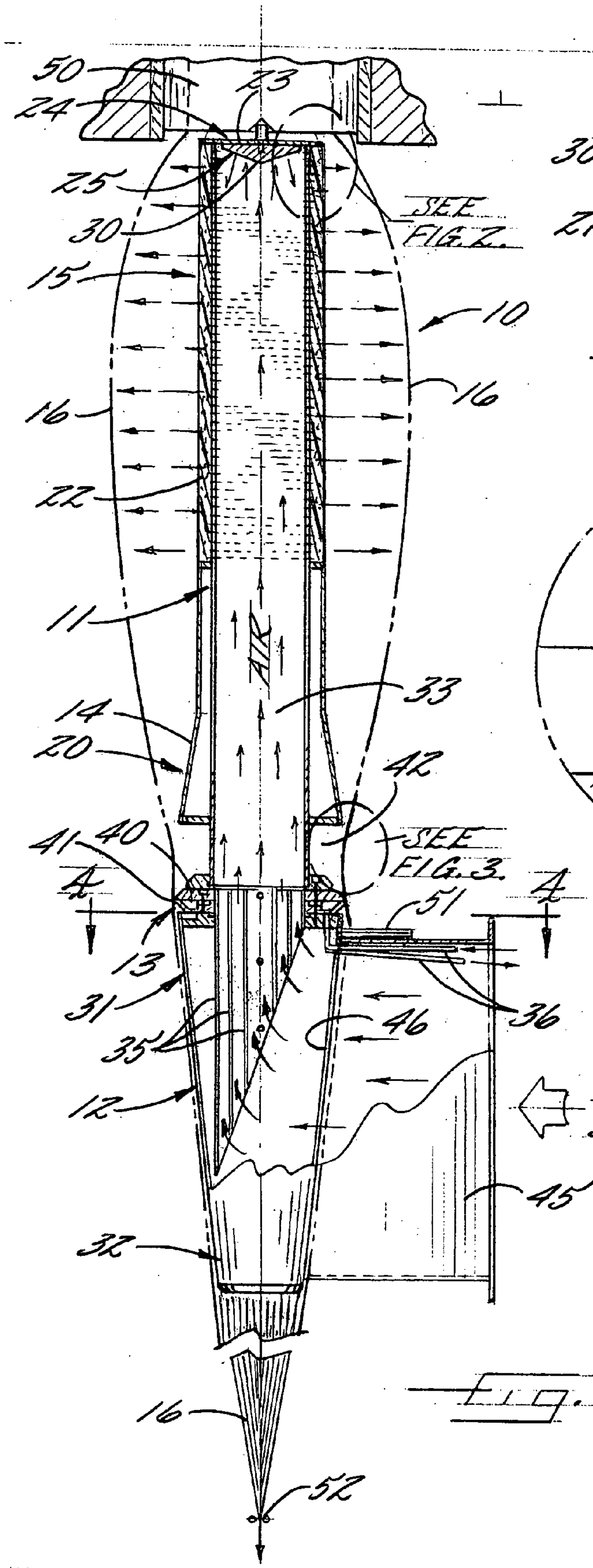


Fig. 1.

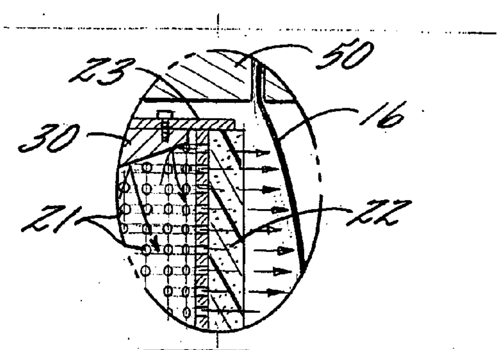


Fig. 2.

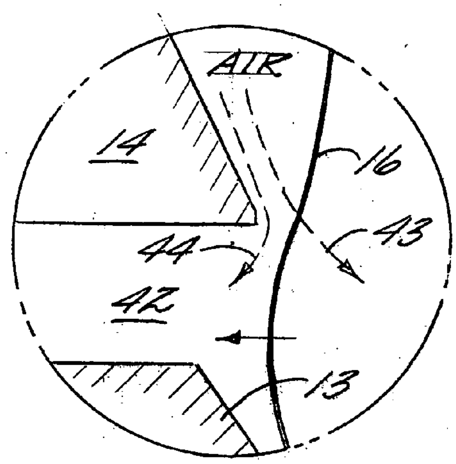


Fig. 3.

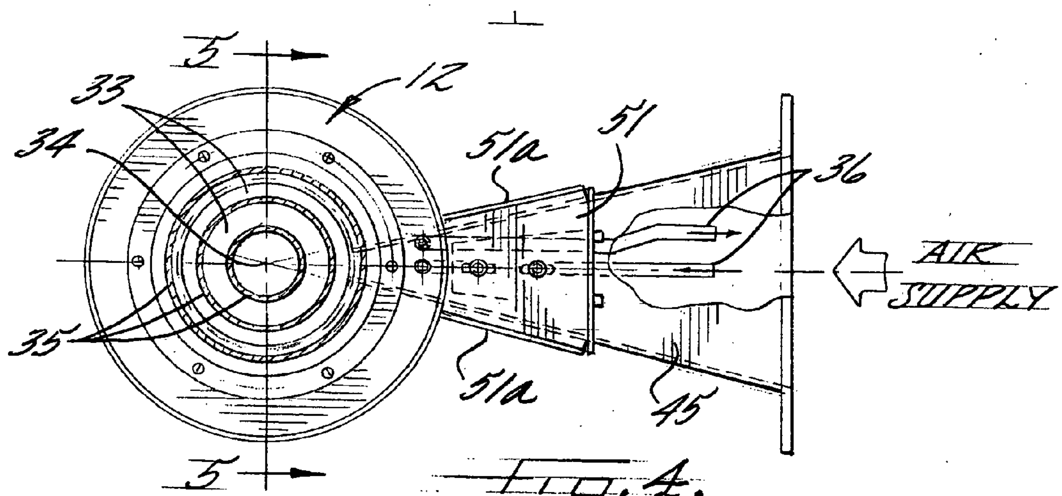


Fig. 4.

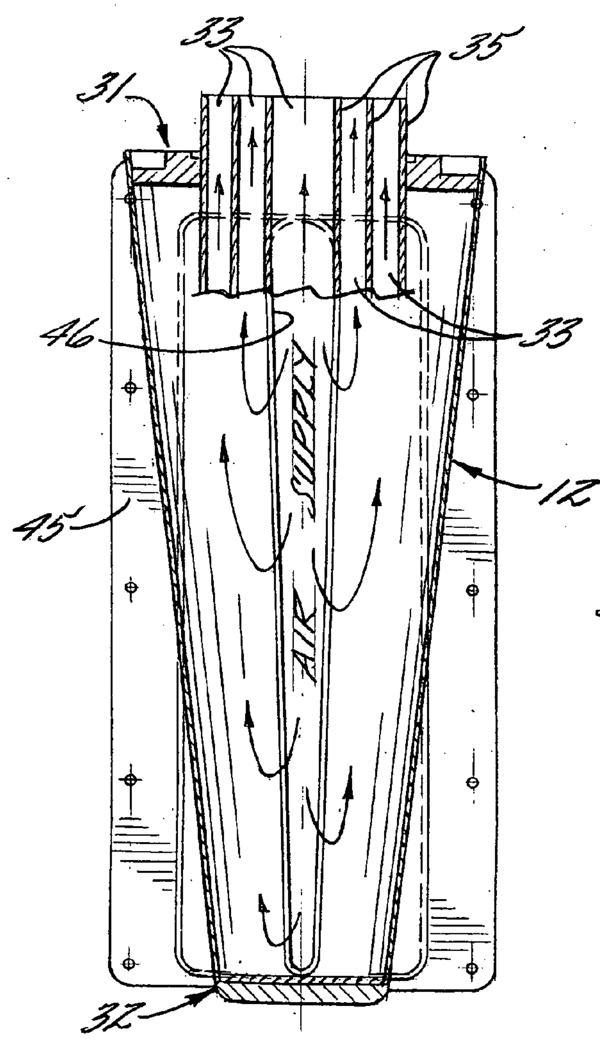


Fig. 5.

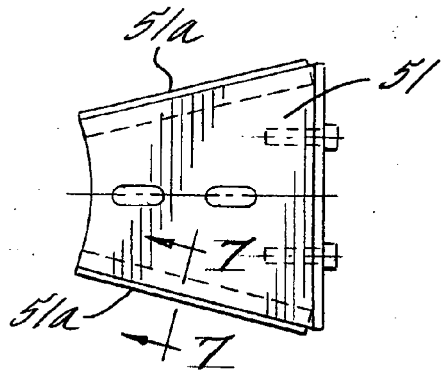


Fig. 6.

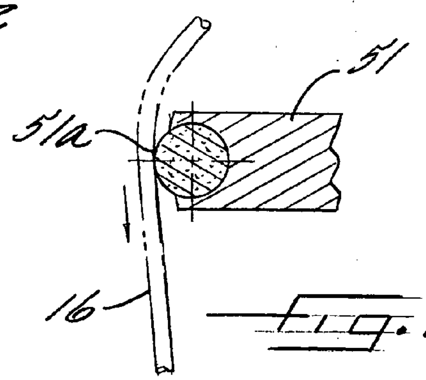


Fig. 7.

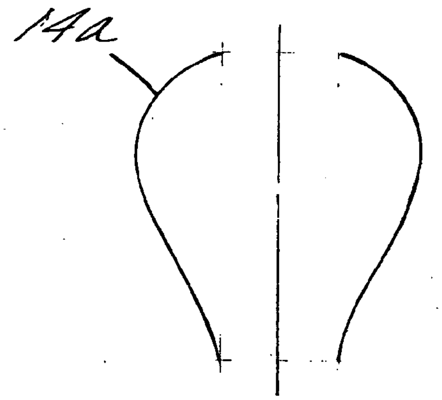


Fig. 8A.

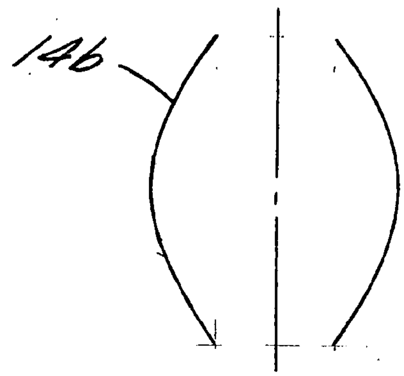


Fig. 8B.

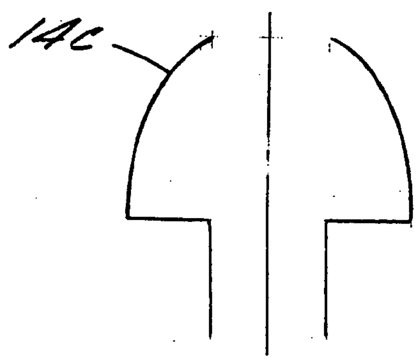


Fig. 8C.

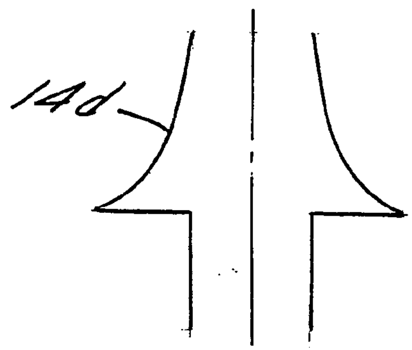


Fig. 8D.

METHOD FOR COOLING AND FINISHING MELT-SPUN FILAMENTS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This is a continuing application of copending U.S. application Ser. No. 10/219,184, filed Aug. 15, 2002, for Apparatus for Cooling and Finishing Melt-Spun Filaments. This copending application is hereby incorporated entirely herein by reference.

FIELD OF THE INVENTION

[0002] The invention relates to an apparatus for cooling and finishing melt-spun filaments. In particular, the invention relates to a hollow quench stick tube that incorporates a spoiler skirt and a finish applicator that are spaced apart to form a spoiler void. The spaced arrangement of the spoiler skirt and finish applicator facilitates the creation of a partial vacuum in the spoiler void to draw a filament stream inwardly against the finish applicator such that the individual filaments are stabilized and sufficiently lubricated with a desired finishing agent. In another aspect, the invention is a method for cooling and finishing melt-spun filaments that incorporates the apparatus wherein the filament stream is drawn inwardly against the finish applicator.

BACKGROUND OF THE INVENTION

[0003] The process in which a fiber-forming substance is melted and then extruded into air or other gas where the substance is cooled and solidified is known as melt spinning. Melt spinning is typically used for the manufacture of polyester and nylon. Various apparatus and methods exist for cooling and finishing melt-spun filaments. Existing apparatus incorporate spinnerets for extruding the filament, cooling tubes for lowering the temperature of the melt-spun filaments as they exit the spinneret, finish applicators for applying desired finishing agents, and filament guides for directing the filament stream towards the finish applicator and onto wind-up units for collecting the finished filament.

[0004] The finishing process, whereby finishing agents are applied to the cooled filaments, is a critical aspect of the melt-spinning process. Specifically, filaments are coated with a desired finishing agent, for example, a lubricating agent, to ensure that the structure of the filaments is not damaged during processing. Damaged filaments are not suitable for use in later processes. Existing apparatus address the problem of applying a sufficient amount of desired finishing agent to filaments. Specifically, known devices incorporate complex mechanisms for delivering the finishing agent and convergence devices for drawing individual filaments into a single thread. Unfortunately, these known devices are prone to mechanical failure (e.g., valve failure and clogging) and place additional, potentially damaging, strain on the individual filaments forming the filament stream.

[0005] For example, U.S. Pat. No. 5,886,055 to Schwarz discloses an apparatus and process for producing polyester multifilament yarn. Schwarz discloses a cooling tube for dispersing air against a filament stream, a downstream sealed tube connected to the cooling tube, a finish applicator connected to the lower end of the sealed tube, and a conical mantle that optionally encloses the sealed tube. As described, Schwarz relies on a convergence device to direct the filament stream against the finish applicator and to combine the individual filaments into one thread. Thus, Scwharz depends upon the convergence device to ensure that the individual filaments contact the finish applicator. Nevertheless, existing convergence devices fail to adequately control the lateral movement (i.e., oscillation) of upstream sections of the filament stream that are adjacent the finish applicator. In other words, known convergence devices affect the downstream sections of the filament stream, yet fail to prevent lateral movement of upstream sections of the filament stream, and specifically, upstream sections affected by air drawn downwardly by the filament stream (i.e., entrained air). Thus there exists a need for an apparatus and method that controls the lateral movement of the filament stream adjacent the finish applicator.

[0006] U.S. Pat. No. 6,174,474 B1 to Stein describes an apparatus and method for producing microfilament yarns with increased titer uniformity. Stein discloses a cone-shaped filament guide secured to a downstream section of a cooling tube that directs air against a filament stream to prevent contact between the filaments and filament guide. The cone-shaped filament guide accelerates entrained air and creates an air cushion that prevents filaments from contacting the filament guide and damaging the filament structure. Stein further discloses finish applicators that are separate from (i.e., not connected to) the cooling tube. Although the cone-shaped filament guide of Stein addresses the problem of preventing the oscillation of filaments at an upstream portion of the filament stream (i.e., prevent contact with the filament guide), it fails to address the problem of ensuring the application of sufficient finishing agent to the individual filaments. Rather, Stein positions the finish applicator below the cooling tube and incorporates the finish applicator as a convergence device. Unfortunately, the separation of the finish applicator from the cooling tube increases the amount of space required to operate the apparatus. Accordingly, there exists a need for a cooling and finishing apparatus in which the cooling tube and finish applicator are integrated and require less space during operation.

[0007] U.S. Pat. No. 4,988,270 to Stibal discloses an apparatus for cooling and conditioning melt-spun material. The Stibal devise includes a dispersing head, a multi-channel finish applicator, and a baffled opening at a downstream section of the dispersing head. Stibal relies upon a mechanically complicated valve seat, valve closure, and spike adjacent the upper end of the dispersing head to create an area of negative pressure to draw filaments into contact with the finish applicator. The valves and valve seats are prone to mechanical breakdown that results in downtime for maintenance periods. Thus, there exists a need for a mechanically reliable apparatus for cooling and finishing melt-spun filaments.

[0008] Existing methods for cooling and finishing filaments as disclosed in the above patents incorporate the devices described therein. Accordingly, there exists a need for a method of cooling and finishing filaments that control filament oscillation adjacent the finish applicator and that incorporates mechanically reliable apparatus.

SUMMARY OF THE INVENTION

[0009] It is therefore an object of the present invention to provide an apparatus and method for cooling and finishing melt-spun filaments that controls the lateral movement of the filament stream adjacent the finish applicator.

[0010] Yet another object of the invention is the provision of an apparatus and method for cooling and finishing melt-spun filaments that includes an integrated cooling tube and finish applicator to minimize the space required during operation.

[0011] A further object of the invention is the provision of an apparatus and method for cooling and finishing melt-spun filaments that is mechanically reliable and reduces the amount of downtime required for maintenance.

[0012] Still another object of the invention is the provision of a method of cooling and finishing melt-spun filaments that controls filament oscillation adjacent the finish applicator and that incorporates mechanically reliable apparatus.

[0013] The invention meets these objectives with an apparatus for cooling and finishing melt-spun filaments. In particular, the invention is a hollow quench stick tube, a finish applicator that substantially surrounds the hollow quench stick tube, and a spoiler skirt that substantially surrounds the hollow quench stick tube and that is spaced apart from the finish applicator to define a spoiler void. In another aspect, the invention is a method for cooling and finishing melt-spun filaments that incorporates the apparatus wherein a partial vacuum created in the spoiler void draws the filaments inwardly against the finish applicator.

[0014] The foregoing and other objects and advantages of the invention and the manner in which the same are accomplished will become clearer based on the following detailed description taken in conjunction with the accompanying drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] **FIG. 1** is a side view of a preferred embodiment of the hollow quench stick tube formed of a hollow cooling tube and a hollow support tube that illustrates air from an air supply entering the hollow support tube, flowing upwardly into the hollow cooling tube, exiting the hollow cooling tube, and flowing against a filament stream.

[0016] **FIG. 2** is an enlarged detailed sectional view of an upper end of the hollow cooling tube depicting flowing air exiting a plurality of openings defined by the hollow cooling tube and cooling the filament stream.

[0017] **FIG. 3** is an enlarged detailed sectional view of a spoiler skirt deflecting the flowing air and creating a partial vacuum in a spoiler void.

[0018] **FIG. 4** is a top plan view taken generally along lines **4-4** of **FIG. 1** depicting a support fin, filament guide, and channels for supplying finishing agent to the finish applicator.

[0019] **FIG. 5** is an enlarged partial side view taken along lines **5-5** of **FIG. 4** illustrating a plurality of flow dividers housed within the hollow support tube that divert flowing air upwardly into the hollow cooling tube.

[0020] **FIG. 6** is an enlarged top plan view of the filament guide.

[0021] **FIG. 7** is an enlarged partial view taken generally along lines **7-7** of **FIG. 6** depicting the filament guide directing a filament around the support fin.

[0022] **FIGS. 8A, 8B, 8**C, and **8**D are side views of alternative shapes of the spoiler skirt.

DETAILED DESCRIPTION OF THE INVENTION

[0023] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which a preferred embodiment of the invention is shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

[0024] It will be understood to those skilled in the art that the concept of an element being "adjacent" another element does not necessarily imply that the elements are contiguous (i.e., in intimate contact). Rather, as used herein, the concept of an element being adjacent another element is meant to describe the relative positions of the elements wherein the elements are in close proximity. Furthermore, it will be understood that the concept of one element being adjacent another element does not necessarily imply contact, but may imply absence of anything of the same kind between the elements.

[0025] It will be understood that the term "spoiler void" refers to a space defined by the maximum diameter of the spoiler skirt, the maximum diameter of the finish applicator, and the periphery of the hollow quench stick tube.

[0026] It will be further understood that the term "ambient air" refers to the air existing or present on all sides of the quench stick tube.

[0027] It will be appreciated by those skilled in the art that the term "pressure differential" refers to the difference in standard atmospheric pressure expressed in millibars between one area and an adjacent area. Further it will be understood that the term "partial vacuum" refers to a defined space having a pressure below atmospheric pressure.

[0028] As used herein, it will be further understood that the term "sleeve" refers to a tubular element that is capable of fitting over or substantially surrounding another element.

[0029] It will also be understood by those skilled in the art that the term "periphery" refers to the external boundary or surface of a body.

[0030] Further, the term "diameter" refers to the distance of a straight-line segment passing through the center of a body.

[0031] It will be also understood that the term "entrained air" refers to air that is drawn downwardly by the downwardly moving filament stream.

[0032] The term "angle of deflection" refers to the angle between a vertical line drawn from the outermost diameter of the top of the spoiler skirt to the bottom of the spoiler skirt and a line drawn from the outermost diameter of the top of the spoiler skirt to the outermost diameter of the spoiler skirt body. Stated differently, the angle of deflection refers to the angle defined by a line representing the height of the spoiler skirt and a line representing the outermost side of the spoiler skirt body.

[0033] As used herein, it will be understood that the term "finishing" refers to the processes through which a filament is passed after extruding and cooling in preparation for incorporation into later processes. It will also be understood by those skilled in the art that finishing includes such operations as the application of chemicals that change the character of the filament.

[0034] Further, as used in conjunction with the term "agent", "finishing agent" will be understood by those skilled in the art to refer to the chemicals used in the finishing processes (e.g., lubricants).

[0035] It will be further appreciated by those of ordinary skill in the art that, as used herein, the concept of an element "substantially surrounding" another element does not necessarily imply that the elements are contiguous (i.e., in intimate contact). Rather, as used herein, the concept of one element substantially surrounding another element is meant to describe the relative positions of the elements within the quench stick tube structure, respectively.

[0036] An overall view of the hollow quench stick tube **10** for cooling and finishing melt-spun filaments **16** that incorporates features of the present invention is set forth in **FIG. 1**. A preferred embodiment of the hollow quench stick tube **10** includes a hollow cooling tube **11**, a hollow support tube **12**, a finish applicator **13**, and a spoiler skirt **14**. As depicted in **FIG. 1**, the hollow quench stick tube **10** is formed of the hollow cooling tube **11** and the hollow support tube **12**. In a preferred embodiment, the hollow quench stick tube **10** is substantially circular. As preferably configured, the hollow cooling tube **11**, hollow support tube **12**, finish applicator **13**, and spoiler skirt **14** are coaxial.

[0037] The hollow cooling tube **11** includes an upper end **15** and a lower end **20**. The hollow cooling tube **11** defines a plurality of openings **21** positioned along its periphery for dispersing a flow of supplied air. During operation, an air supply may provide the flowing air to the hollow quench stick tube **10**. The plurality of openings **21** is preferably positioned above the spoiler skirt **14**. It will be understood by those skilled in the art that the hollow cooling tube **11** may be formed from any material that provides uniform, non-turbulent air flow from the quench stick tube **10** to the filaments **16**. For example, the hollow cooling tube **11** may be formed from multiple layers of mesh screen, sintered metal, or filter material sold under the trademark PORO-PLATE®.

[0038] A dispersal sleeve **22** that substantially surrounds a portion of the hollow cooling tube **11** is provided to evenly distribute flowing air exiting the plurality of openings **21**. Specifically, the dispersal sleeve **22** disseminates flowing air that advances upwardly along an interior portion of the hollow quench stick tube **10** and exits from the plurality of openings **21**. Advantageously, the dispersal sleeve **22** also filters airborne contaminants in the flowing air. The dispersal sleeve **22** is preferably constructed of foam that facilitates the even distribution of flowing air during operation. Nevertheless, it will be understood that the dispersal sleeve **22** may be formed from any porous media that is capable of evenly dispersing flowing air. For example, the dispersal sleeve may be formed from overlapping wire (i.e., wire mesh) woven textile material, or non-woven textile material. In a preferred embodiment, the dispersal sleeve **22** substantially surrounds an upper portion **15** of the hollow cooling tube **11** that defines the plurality of openings **21**. Stated differently, the dispersal sleeve **22** may be positioned adjacent the plurality of openings **21**.

[0039] Upon entry into the hollow cooling tube **11**, the flowing air is collected and dispersed through the openings **21**. See **FIG. 2**. Accordingly, the invention provides a cover plate **23** having a top surface **24** and a bottom surface **25** that is secured to the upper end **15** of the hollow cooling tube **11**. As arranged, the cover plate **23** facilitates the collection of the flowing air by sealing the upper end **15** of the hollow cooling tube **11**.

[0040] As shown in **FIG. 1**, the hollow cooling tube **11** further provides an air director **30** that is secured to the bottom surface **25** of the cover plate **23**. In operation, the air director **30** is capable of deflecting flowing air that advances upwardly from the hollow support tube **12** along the hollow cooling tube **11** into the plurality of openings **21**. Advantageously, the air director **30** prevents substantial fluctuations in the pressure of the flowing air in the hollow cooling tube **11**. Stated differently, the air director **30** promotes a consistent pressure gradient along the length of the hollow cooling tube **11**. The consistent pressure of the flowing air ensures an even distribution of the air into the plurality of openings **21** and against the filament stream **16**.

[0041] The hollow support tube **12** includes an upper end **31** and a lower end **32**. With reference to the orientation of the hollow quench stick tube **10** depicted in **FIG. 1**, the upper end **31** of hollow support tube **12** is connected to the lower end **20** of the hollow cooling tube **11**. The hollow cooling tube **11** and hollow support tube **12** are aligned to correspondingly define a common pathway **33** within the hollow quench stick tube **10**. Referring to **FIG. 4**, a central axis **34** of the hollow quench stick tube **10** further defines the common pathway **33**. During operation, the common pathway **33** serves as an air path for directing a flow of supplied air.

[0042] In a preferred embodiment, the hollow support tube **12** is substantially conical in shape as illustrated in **FIGS. 1 and 5**. The hollow support tube **12** incorporates a plurality of flow dividers **35** depicted in **FIG. 4** that are capable of directing flowing air from the air supply upwards along the common pathway **33** into the hollow cooling tube **11**. The plurality of flow dividers **35** is preferably formed of steel, aluminum, or similar hardened material of sufficient strength to withstand forces exerted by the flowing air. The flow dividers **35** are preferably secured to interior surfaces of the hollow support tube **12** and oriented in such a manner as to direct flowing air entering the hollow support tube into the hollow cooling tube **11**. Accordingly, the flow dividers **35** may include a plurality of substantially circular vanes arranged in a concentric pattern.

[0043] Referring to **FIG. 1**, the finish applicator **13** substantially surrounds the hollow quench stick tube **10**. As depicted, the finish applicator **13** is connected to the outer surface of the hollow quench stick tube **10**. In a preferred embodiment, the finish applicator **13** is connected to the upper end **31** of the hollow support tube **12**. Nevertheless, it will be understood that an alternative embodiment of the invention may include a finish applicator **13** that is connected to the lower end **20** of the hollow cooling tube **11**. It will also be understood that the finish applicator **13** may be connected to the upper end **31** of the hollow support tube **12** and the lower end **20** of the hollow cooling tube **11**. The finish applicator **13** may be secured to the hollow support tube **12** or hollow cooling tube **11** by any number of bolts, pins, or similar securing devices.

[**0044**] The finish applicator **13** is in communication with a supply of finishing agent via a conduit **36**. The finish applicator **13** also defines a receptacle **40** for containing a desired amount of finishing agent, wherein the receptacle is in communication with the conduit **36**. Accordingly, during operation, finishing agent is supplied to the finish applicator **13** via the conduit **36**. The periphery of the finish applicator **13** includes an opening **41** that leads to the receptacle **40** such that finishing agent from the receptacle exits the opening and coats the filament stream **16** as the individual filaments contact the periphery of the finish applicator.

[**0045**] As illustrated in **FIG. 4**, the spoiler skirt **14** is substantially circular and surrounds the hollow quench stick tube **10**. In a preferred embodiment, the spoiler skirt **14** is connected to the hollow quench stick tube **10**. In a more preferred embodiment, the spoiler skirt **14** is connected to the hollow cooling tube **11**. Nevertheless, it will be understood that the spoiler skirt **14** may be connected to the hollow support tube **12** or finish applicator **13** in an arrangement whereby the spoiler skirt substantially surrounds the hollow quench stick tube **10**, yet does not interfere with the filament stream **16**.

[**0046**] A preferred embodiment of the spoiler skirt **14** is preferably positioned above the finish applicator **13**. Specifically, the spoiler skirt **14** is spaced apart from the finish applicator **13**. The construction of the hollow quench stick tube **10** permits the spoiler skirt **14** and finish applicator **13** to define a spoiler void **42**. As used herein, the spoiler void **42** is defined by the maximum diameter of the spoiler skirt **14**, the maximum diameter of the finish applicator **13**, and the periphery of the hollow quench stick tube **10**.

[**0047**] With reference to the orientation of the invention as illustrated in **FIG. 1**, the spoiler skirt **14** flares outwardly from top to bottom forming a substantially smooth transition to alter the direction of the entrained air (i.e., flowing air drawn downwardly by the filament stream). Advantageously, the shape of the preferred embodiment of the spoiler skirt **14** facilitates the creation of a partial vacuum in the spoiler void **42**. Specifically, the spoiler skirt **14** directs entrained air from a position adjacent the hollow quench stick tube **10** outwardly, against and through the filament stream **16**, thereby creating an area of negative pressure (i.e., partial vacuum) between the bottom of the spoiler skirt and the top of the finish applicator **13**. Test results indicate a reduction in pressure of approximately 1 to 5 millibars.

[**0048**] Specifically, the partial vacuum is created by two components of the entrained air acting in combination with ambient air. See **FIG. 3**. First, the flow of entrained air **43** that is forced through the filament stream **16** or wall (i.e., component one of the entrained air) creates a negative pressure in the spoiler void **42** immediately below the spoiler skirt **14**. Second, the remaining entrained air **44** that fails to pass through the filament wall **16** (i.e., component two of the entrained air) accelerates through the narrowed opening between the maximum diameter of the spoiler skirt **14** and the filament wall. This second component of entrained air **44** accelerates as a result of the venturi effect. Stated differently, the narrowed opening between the maximum diameter of the spoiler skirt **14** and the filament wall **16** serves as a venturi to increase the speed of the entrained air **44**, thus creating an area of negative pressure in the spoiler void **42**. The resulting area of negative pressure (i.e., in the spoiler void **42**) created by the entrained air **43**, **44** draws ambient air into the spoiler void, thereby drawing the filament stream **16** inwardly and against the finish applicator **13**.

[**0049**] This negative pressure creates a more stable spinning process by drawing the filament stream **16** towards the finish applicator **13** to thereby reduce the number of filaments oscillating against the finish applicator. The oscillating filaments **16** have intermittent contact with the finish applicator **13** and, thus, are less likely to receive a sufficient coating of finishing agent. By increasing the amount of surface area of each filament **16** that comes in contact with the finish applicator **13**—and finishing agent—the present invention increases the amount of finishing agent applied to the filament. Thus, the invention produces filaments **16** having a more uniform finish distribution and are therefore protected from fiber damage during downstream processing.

[**0050**] In brief, the spoiler skirt **14** creates a divergence of entrained air against the filament stream **16** and a convergence of ambient air into the spoiler void **42**. Advantageously, the partial vacuum created by the partial removal of the entrained air draws the filament stream **16** inward and against the finish applicator **13** such that the individual filaments are sufficiently lubricated with a desired finishing agent. It is known that insufficiently lubricated filaments tend to break or deform.

[**0051**] Further, the design of the spoiler skirt **14** minimizes reliance upon a filament guide or convergence device to assist in the finishing of the filament stream **16**. More specifically, filament guides and convergence devices are generally used downstream to draw individual filaments towards one another and against a finish applicator **13**. Nevertheless, known filament guides fail to reduce turbulence below the cooling tube that is created by entrained air. Turbulence, which is inherent with most conventional devices, causes filament vibration. The vibration oftentimes prevents some filaments from contacting the finish applicator **13**.

[**0052**] The incorporation of differential pressure to draw the filament stream **16** inward towards the hollow quench stick tube **10** and against the finish applicator **13** requires that the spoiler skirt **1414**C, **14**D have an uppermost diameter that is less than the lowermost diameter. See **FIGS. 1, 8**C, and **8**D. In other preferred embodiments, the uppermost diameter of the spoiler skirt **14**, **14**A, **14**B, **14**C, **14**D is less than the maximum diameter of the spoiler skirt. See **FIGS. 8A and 8B**. In other words, the lower portion of the spoiler skirt **14** may taper inwardly, yet maintain a diameter that is less than the uppermost diameter.

[**0053**] The height of the spoiler skirt **14** is proportional to the angle of deflection of the spoiler skirt. Specifically, the ratio of the angle of deflection to skirt height in the preferred embodiment is between 1.35 to 2.78 degrees/inch. Trials indicate that as spoiler skirt **14** height decreases, the reduced surface area of the sides of spoiler skirt fails to deflect sufficient air flow to create a partial vacuum in the spoiler void **42**. For example, a representative ratio of 6.14 degrees/inch results in a skirt having insufficient surface area to create a partial vacuum in the spoiler void **42**. Similarly, as the deflection angle increases, the deflecting surface of the spoiler skirt **14** increases. As a result, the flowing air strikes a greater surface area and creates undesirable turbulent regions adjacent the filament stream.

[**0054**] Trials indicate that increasing the separation between the bottom of the skirt **14** and the top of the finish applicator **13** increases the differential pressure between the area immediately beneath the skirt (i.e., spoiler void **42**) and the area beyond the perimeter of the bottom of the skirt (i.e., adjacent surroundings).

[**0055**] In mathematical terms, the preferred embodiment of the invention is configured such that the ratio of the lowermost diameter of the spoiler skirt **14** to the maximum diameter of the finish applicator **13** is between about 0.86 to 1.0.

[**0056**] Test trials conducted with the present invention identified process variables that influence the negative pressure generated under the spoiler skirt **14**. Those process variables included wind-up speed, throughput, quench airflow, spinneret hole-count, and the distance between the bottom outside diameter of the spoiler skirt **14** and the top outside diameter of the finish applicator **13**.

[**0057**] A spoiler skirt **14** having a top outside diameter of 4.5 inches and a bottom outside diameter of 6.5 inches was spaced above the finish applicator **13** at a distance of 1.5 inches and 2.5 inches, respectively. Tests incorporating a spinneret **50** having a 2250 hole-count indicated that distance between the bottom of the spoiler skirt **14** and top of the finish applicator **13**, throughput, wind-up speed, and quench airflow significantly affected the negative pressure under the spoiler skirt.

[**0058**] Tests incorporating a spinneret **50** having a 3003 hole-count indicated that only the distance between the bottom of the spoiler skirt **14** and top of the finish applicator **13**, and wind-up speed, significantly affected the pressure under the spoiler skirt. All data collected indicated that the distance between the bottom of the spoiler skirt **14** and top of the finish applicator **13**, wind-up speed, hole-count, quench airflow, and throughput significantly impacted the pressure under the skirt.

[**0059**] Based on stepwise regression data, the distance between the bottom of the spoiler skirt **14** and top of the finish applicator **13** and wind-up speed are the dominating variables that influence the pressure under the spoiler skirt. As the distance between the bottom of the spoiler skirt **14** and top of the finish applicator **13** increases, the volume of the spoiler void **42** increases, thereby providing a larger void in which the negative pressure is generated.

[**0060**] As wind-up speed increases during operation, the entrained airflow in the filament stream **16** increases, as well as the velocity of the flowing air. Observations confirmed that the spoiler skirt **14** creates a low-pressure region under the skirt when entrained air is deflected against and through the filament stream. As ambient air adjacent the spoiler void **42** moves to fill the low-pressure region under the skirt, the converging ambient air pulls the filaments inward and against the finish applicator **13**.

[**0061**] The invention may also include a support fin **45** that is connected to the hollow support tube **12** as depicted in **FIGS. 1 and 4**. In a preferred embodiment, the support fin **45** is in communication with the air supply and the hollow support tube **12**. Accordingly, the support fin **45** is in communication with the common pathway **33** (i.e., air path) and is capable of directing flowing air from an air supply along the hollow support tube **12** into the hollow cooling tube **11**. As illustrated in **FIG. 4**, a preferred embodiment of the support fin **45** is triangular in shape. Specifically, the support fin **45** is defined by three sides, wherein two sides converge to form an edge connected to the hollow support tube **12** such that its shape is substantially triangular. It will be understood by those skilled in the art that the shape of the support fin **45** may be rectangular, circular, elliptical, or any shape that facilitates the delivery of supplied air, yet does not interfere with the movement of the filament stream. The support fin **45** may be substantially hollow to facilitate flowing air. Nevertheless, it will be understood that the support fin **45** may define a channel **46** or channels for directing air from the air supply into the hollow support tube **12**.

[**0062**] A preferred embodiment of the invention also includes a spinneret **50** positioned above and substantially adjacent to the upper end of the hollow quench stick tube **10**. See **FIG. 1**. Stated differently, the spinneret **50** is positioned above and substantially adjacent to the upper end **15** of the hollow cooling tube **11**. The spinneret **50** is preferably coaxial with the common pathway **33** defined by the hollow support tube **12** and hollow cooling tube **11**. During operation, the spinneret **50** provides a substantially circular filament stream **16** that flows downwardly and substantially surrounds the hollow quench stick tube **10**.

[**0063**] Trial results of the present invention during operation verify the relationship between the volume of the spoiler void **42** and hole count of the spinneret **50**. Expressed in mathematical terms, the ratio of the volume of the spoiler void **42** to the hole count of the spinneret **50** is between about 0.2 to 0.7 cubic centimeters per number of holes in the spinneret. In a preferred embodiment, the ratio of the volume of the spoiler void **42** to the hole count of said spinneret **50** is between about 0.3 and 0.5 cubic centimeters per number of holes in the spinneret. In a related matter, trials indicate that in the preferred embodiment of the present invention, the ratio of the outside diameter of the bottom of the spoiler skirt **14** to the diameter of the inner row of holes on the spinneret **50** is between 1.12 to 1.37.

[**0064**] A filament guide **51** depicted in **FIGS. 4, 6,** and **7** may also be incorporated into the invention and positioned adjacent to the hollow quench stick tube **10**. As configured, the filament guide **51** is positioned below and spaced apart from the finish applicator **13**. Stated differently, the filament guide **51** is positioned substantially adjacent to the upper end **31** of the hollow support tube **12**. In a preferred embodiment, the filament guide **51** is connected to an upper edge of the support fin **45** to direct the filament stream **16** around the support fin, thereby preventing the individual filaments from contacting the support fin. In an alternative embodiment, the filament guide **51** may be positioned substantially adjacent to the lower end of the hollow cooling tube **20**. The exposed edges **51***a* of the filament guide **51** are preferably made of ceramic. Nevertheless, it will be understood that the filament guide **51** may be formed of any material that prevents the filament stream **16** from adhering to the filament guide.

[0065] The invention may also include a convergence device **52** shown in **FIG. 1** that is positioned below and spaced from the hollow quench stick tube **10**. The convergence device **52** is preferably positioned below and spaced from the hollow support tube **12**. The convergence device **52** may include a ring or similar substantially circular device that directs the individual filaments of the filament stream **16** to a common point for collection on a winding unit.

[0066] Another aspect of the invention includes the use of the apparatus in conjunction with a method for cooling and finishing melt-spun filaments. In a preferred method, an apparatus is provided that includes a hollow quench stick tube **10**, a finish applicator **13** that substantially surrounds the hollow quench stick tube, and a spoiler skirt **14** that substantially surrounds the hollow quench stick tube. The hollow quench stick tube **10** provided defines a plurality of openings **21** positioned along its periphery for dispersing a flow of supplied air. The hollow quench stick tube **10** further defines an air path within the hollow quench stick tube for directing the flowing air. The spoiler skirt **14** provided is positioned above and spaced apart from the finish applicator **13** to thereby define a spoiler void **42**.

[0067] Upon providing the apparatus, a filament stream **16** is spun above an upper end of the hollow quench stick tube **10**. Specifically, a stream of melt spun filaments is extruded above the hollow quench stick tube **10** in such a manner that the filament stream substantially surrounds the hollow quench stick tube. Stated differently, the spinneret **50** spins the filament stream **16** in a substantially circular pattern.

[0068] Next, a flow of supplied air is pumped into the hollow quench stick tube **10**. Upon entering the hollow quench stick tube **10**, the flowing air is directed upwardly along the air path by, for example, a plurality of flow dividers **35**. Upon reaching the upper end of the hollow quench stick tube **10**, the flowing air is dispersed through the plurality of openings **21**. Upon exiting the openings **21**, the air is directed against the filament stream **16**. The downwardly moving filament stream **16** causes the flowing air to become entrained—i.e., the downwardly moving filament stream **16** draws the flowing air downwardly. The flowing air cools the filament stream **16** as it initially strikes the filament stream. Specifically, the majority of cooling occurs approximately ten inches below the point of extrusion.

[0069] Advantageously, the flowing air passing over the outer surface of the spoiler skirt **14** and adjacent the spoiler void **42** creates a negative pressure differential between the spoiler void and the adjacent surroundings. Specifically, the entrained air **43** that passes through the filament wall **16**, and the entrained air **44** that passes through the narrow opening between the outer diameter of the spoiler skirt **14** and the filament wall (i.e., venturi), creates a negative pressure area in the spoiler void **42**. As a result, ambient air is drawn into the spoiler void **42** having a negative pressure area. The flow of ambient air into the spoiler void **42** draws the filament stream **16** inwardly and against the finish applicator **13**.

[0070] Finally, the filament stream **16** is finished with a desired agent. More specifically, the step of finishing includes applying a desired finishing agent to the filament stream **16**. During the finishing step, filaments **16** are coated by a finishing agent provided by the finish applicator **13** when the filament stream is drawn inwardly into the spoiler void **42** and against the perimeter of the finish applicator.

[0071] As practiced, the method provides a pressure differential between the spoiler void **42** and the adjacent surrounding between about 1 to 5 millibars. Further, the velocity of the flowing air moving from an upper end of the hollow quench stick tube **10** to a lower end of the hollow quench stick tube (i.e., through the hollow quench stick tube) is between about 75 and 315 per minute (fpm). The method further provides for the cooling and finishing of the melt-spun filaments **16** at a draw ratio of between about 1.5 and 3.75.

[0072] In the drawings and specification, there have been disclosed typical embodiments on the invention and, although specific terms have been employed, they have been used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

That which is claimed is:

1. A method of cooling and finishing melt-spun filaments, the method comprising the steps of:

providing an apparatus comprising:

a hollow quench stick tube defining a plurality of openings positioned along its periphery, and an air path within the hollow quench stick tube;

a finish applicator substantially surrounding the hollow quench stick tube; and

a spoiler skirt substantially surrounding the hollow quench stick tube, wherein the spoiler skirt is positioned above and spaced apart from the finish applicator to thereby define a spoiler void;

spinning a filament stream;

pumping a flow of supplied air into the hollow quench stick tube;

dispersing air through the plurality of openings;

cooling a stream of filaments with the flowing air;

diverting the flowing air to create a pressure differential between the spoiler void and adjacent surroundings that draws the filament stream against the finish applicator; and

finishing the filament stream with a desired finishing agent.

2. A method according to claim 1, wherein the step of spinning comprises extruding a stream of melt-spun filaments above the hollow quench stick tube such that the filament stream substantially surrounds the hollow quench stick tube.

3. A method according to claim 1, wherein the step of pumping comprises directing the flowing air upwardly along the air path.

4. A method according to claim 1, wherein the step of dispersing comprises directing the flowing air against the filament stream, such that the filament stream draws the flowing air downwardly.

5. A method according to claim 1, wherein the step of diverting comprises directing the downwardly flowing air through the filament stream and into the adjacent surroundings, whereby the flowing air passing through the filament stream creates a negative pressure differential between the spoiler void and the adjacent surroundings.

6. A method according to claim 1, wherein the step of diverting further comprises directing the downwardly flowing air into a space between the spoiler skirt and filament stream, whereby the flowing air accelerated into the spoiler void creates a negative pressure differential between the spoiler void and the adjacent surroundings.

7. A method according to claim 1, wherein the step of finishing comprises applying a desired finishing agent to the filament stream.

8. A method according to claim 1, wherein the pressure differential between the spoiler void and the adjacent surroundings is between about 1 to 5 millibars (mb).

9. A method according to claim 1, wherein the velocity of the flowing air moving from an upper end of the quench stick tube to a lower end of the quench stick tube is between about 75 and 315 feet per minute.

10. A method according to claim 1, wherein the draw ratio of the filament stream is between about 1.5 and 3.75.

11. A method of cooling and finishing melt-spun filaments, the method comprising the steps of:

spinning a stream of filaments about a hollow quench stick tube having a plurality of openings along its periphery;

dispersing a flow of supplied air into the hollow quench stick tube and through the plurality of openings to thereby cool the filament stream with the flowing air;

diverting the flowing air to create a pressure differential between a lower portion of the hollow quench stick tube and adjacent surroundings, such that the pressure differential draws the filament stream against a finish applicator; and

finishing the filament stream with a desired finishing agent.

12. A method according to claim 11, wherein the step of spinning comprises extruding a stream of melt-spun filaments above the hollow quench stick tube such that the filament stream substantially surrounds the hollow quench stick tube.

13. A method according to claim 11, wherein the step of dispersing comprises directing the flowing air against the filament stream, such that the filament stream draws the flowing air downwardly.

14. A method according to claim 11, wherein the step of diverting comprises directing the downwardly flowing air through the filament stream and into the adjacent surroundings, whereby the flowing air passing through the filament stream creates a negative pressure differential between the lower portion of the hollow quench stick tube and the adjacent surroundings.

15. A method according to claim 11, wherein the step of finishing comprises applying a desired finishing agent to the filament stream.

16. A method according to claim 11, wherein the velocity of the flowing air through the hollow quench stick tube is between about 75 and 315 feet per minute.

17. A method according to claim 11, wherein the draw ratio of the filament stream is between about 1.5 and 3.75.

18. A method of cooling and finishing melt-spun filaments, the method comprising the steps of:

spinning a stream of filaments;

pumping a flow of supplied air into a hollow quench stick tube;

dispersing a flow of supplied air through a plurality of openings defined by the hollow quench stick tube;

cooling the filament stream with the flowing air;

diverting the flowing air to create a pressure differential at a lower portion of the hollow quench stick tube; and

finishing the filament stream with a desired finishing agent;

wherein the pressure differential draws the filament stream against a finish applicator that substantially surrounds the hollow quench stick tube.

19. A method according to claim 18, wherein the step of pumping comprises directing the flowing air upwardly into the hollow quench stick tube.

20. A method according to claim 18, wherein the step of dispersing comprises directing the flowing air against the filament stream, such that the filament stream draws the flowing air downwardly.

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