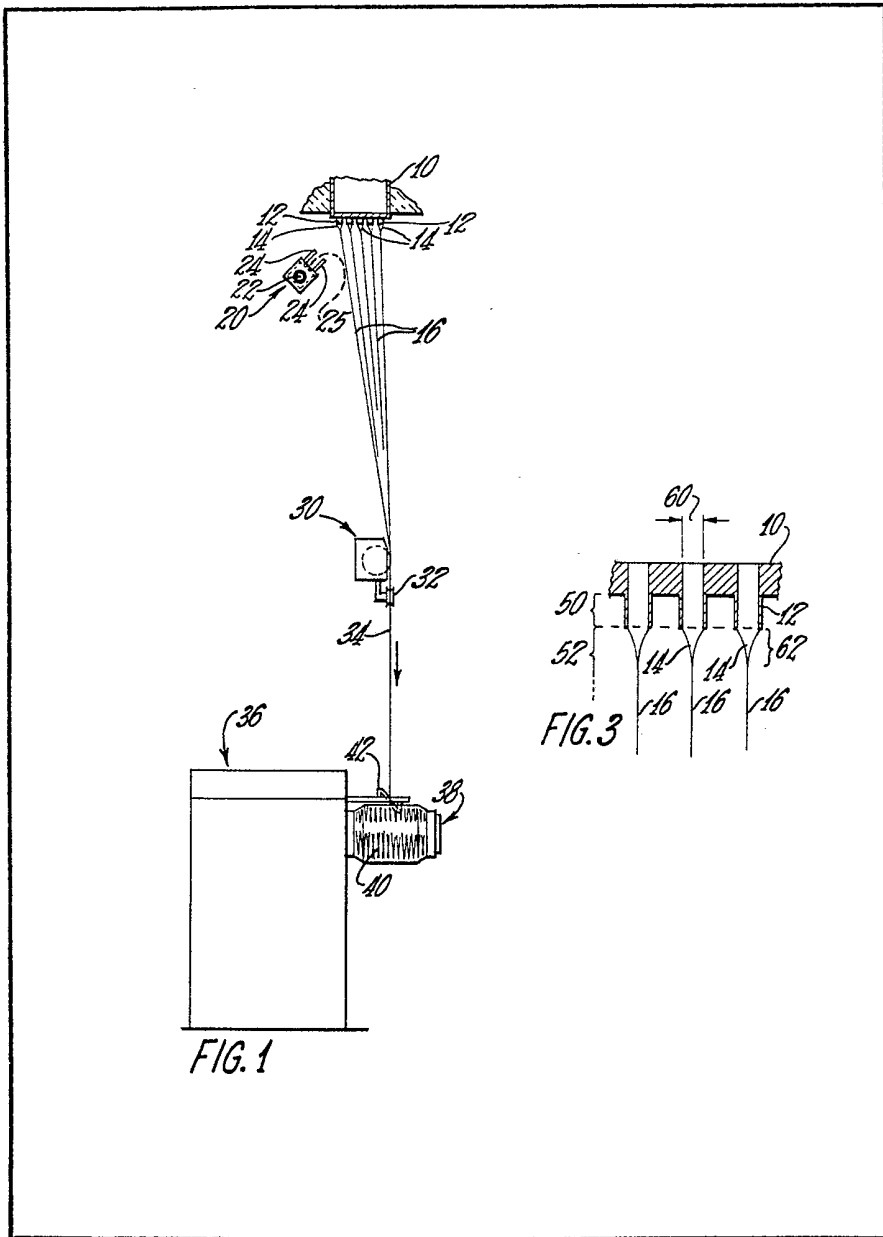


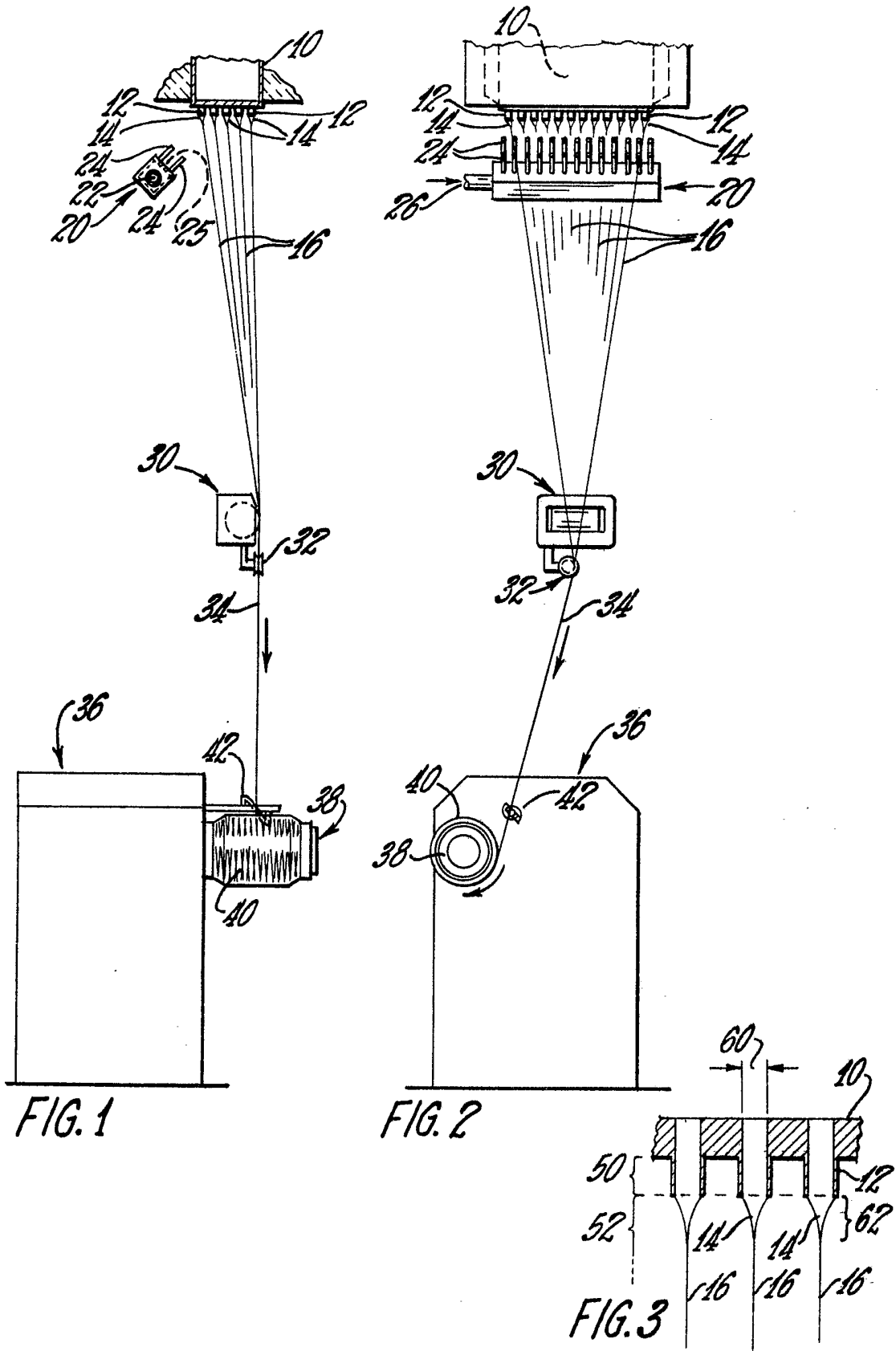
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(54) **Method and Apparatus for Manufacturing Glass Fibers**

(57) Streams of molten glass are flowed from a stream feeder through orificed projections which depend from the feeder floor and are compactly arranged to provide a quiescent layer of gas against the feeder floor, a gas is directed upwardly

into contact with the streams of molten glass at a velocity and in an amount effective to convey away from the streams sufficient heat to render the glass of the streams attenuable to fibers without appreciably disturbing the layer of gas above the streams in the region between the orificed projections, and fibers are attenuated from the streams of molten glass.





SPECIFICATION

Method and Apparatus for Manufacturing Glass Fibers**Background of the Invention**

5 In recent years, there has been considerable interest in the production of glass fibers. Due to the tremendous usages of glass fibers, this interest has been particularly focused on increasing the production of individual fiber forming stations.

10 In the production of fibers, molten glass is typically passed through tips or orifices in a bushing to create individual fibers. As the molten streams of glass flow through the tips or orifices for attenuation into fibers, the fiber forming environment below the bushing must be carefully controlled for a stable fiber forming operation.

15 Glass fiber forming bushings today conventionally have a plurality of tips projecting below the bushing floor through which streams of molten glass flow. Cones of glass form at the exit area of each tip and fibers are attenuated therefrom. The fiber forming environment in the cone region must be carefully controlled.

25 Conventionally, this is done by placing solid metallic heat exchanging units or finshields beneath the bushing and between rows of tips. Such finshield units have been used for many years to control the fiber forming region beneath a bushing.

30 Over the years, the number of fibers produced by a single bushing has increased greatly. In the past it was common for a bushing to produce about 200 fibers. Today bushings can produce 2000, or more, fibers. As the number of fibers per bushing continues to increase, problems with conventional fiber forming processes and apparatus have arisen. When using conventional finshield units to control the fiber forming environment, one is limited in the tip density that can be employed in the fiber forming bushing as there must be sufficient space for the fin members to project between rows of tips. Thus, to increase the number of fibers being formed by a single bushing, the physical size of the bushing must be increased. With bushings of increased size and increased glass throughput per tip, solid finshield members are operated at the very upper limit of their physical heat transfer capability.

45 As bushings are produced to create even larger numbers of fibers per bushing and as the throughput per bushing tip or orifice is increased, environmental control by conventional finshield units can be inadequate. There has been considerable activity in the glass fiber forming field to develop a process and apparatus for controlling the fiber forming environment in such bushings.

50 One such glass fiber forming process describes the elimination of the need for conventional finshields.

55 This process utilizes a bushing having a flat orifice plate with closely packed non-tipped orifices and a lower air nozzle from which an

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65 upwardly directed flow of air issues to impinge directly on the orifice plate. The process teaches that the orifice density of such a bushing can be greatly increased over that of a conventional bushing using conventional finshields. The

70 impingement of the cooling air directly upon the orifice plate to flow outwardly along the plate cools the molten glass cones to maintain fiber separation and to eliminate any stagnant air at the under surface of the plate. Problems can arise

75 in maintaining a stable glass fiber forming operation with this process. Problems can also arise in restarting this process after there is an interruption in the formation of fibers. After a fiber forming interruption and a tipless bushing does

80 not form heads of glass at each orifice as does a tipped bushing. Restarting such an orificed bushing requires a very skilled operator and the restarting operation is quite time-consuming.

85 Improvements in the glass fiber forming process and apparatus are desired.

This invention is aimed at increasing the production of glass fibers from a single bushing without the attendant difficulties of tipless bushings or feeders.

90 In accordance with one aspect of this invention, there is provided a method of forming glass fibers from orificed projections of a stream feeder comprising:

95 a) drawing streams of glass from the orificed projections while maintaining a quiescent layer of gas in contact with the orificed projections, the streams of glass forming cones of glass at the discharge end of the orificed projections; and

100 b) directing a gas upwardly into contact with the cones of glass proximate the orificed projections to cool said glass in the absence of any substantial disturbance of said layer of gas.

105 Also, according to this invention there is provided a method of forming glass fibers comprising:

110 a) flowing streams of glass from a stream feeder through orificed projections depending from the feeder floor;

115 b) attenuating fibers from cones of molten glass formed at each orifice, the orificed projections being in close compacted relation to promote the retention of a thermally insulating layer of heated air adjacent the feeder floor; and

120 c) directing gas upwardly into contact with the cones of glass at a velocity and in an amount to convey from the cones of glass sufficient heat to control the temperature of the glass of the cones to render the glass attenuable to fibers without appreciably affecting the layer of heated air.

125 Also, according to this invention there is provided apparatus for forming glass fibers comprising:

a) a stream feeder having orificed projections in its floor and means for drawing streams of glass issuing from the orificed projections into fibers with the streams of glass forming cones of glass at the discharge end of the orificed projections, wherein the orificed projections are in close compacted formation to promote the

retention of a thermally insulating layer of gas adjacent the feeder floor; and

b) means for directing gas upwardly into contact with the cones of glass at a velocity and in an amount to convey from the cones of glass sufficient heat to render the glass of the cones attenuable to fibers while leaving the thermally insulating layer of gas substantially undisturbed.

In addition, according to this invention there is provided apparatus for forming glass fibers comprising:

a) means for flowing streams of glass from a stream feeder through orificed projections depending from the feeder floor;

b) means for attenuation fibers from cones of molten glass formed at each orifice, the orificed projections being in close compacted relation to promote the retention of a layer of heated air adjacent the feeder floor; and

c) means for directing gas upwardly into contact with the cones of glass at a velocity and in an amount to convey from the cones of glass sufficient heat to control the temperature of the glass of the cone to render the glass attenuable to fibers without appreciably affecting the layer of heat air at the region of the orificed projections.

An embodiment of the invention is hereafter described with reference to the accompanying drawings, in which:—

Fig. 1 is a front elevational view of a glass fiber forming operation in accordance with the present invention.

Fig. 2 is a side elevational view of the glass fiber forming operation shown in Fig. 1.

Fig. 3 is a partial cross-sectional view of a bushing in accordance with the present invention.

These drawings are generally illustrative of the method and apparatus for carrying out the invention but are not to be considered as limiting the invention to the specifics thereof.

Description of the Preferred Embodiments

Referring now more particularly to the drawings, Figs. 1 and 2 illustrate a fiber forming operation. Mineral material, such as glass, is maintained in a molten condition in the bushing or stream feeder assembly 10 from which a plurality of streams of material is emitted from orificed tips or projections depending from the bushing or feeder floor. The streams of glass form cones of glass 14 at the discharge end of the orificed projections. Glass fibers 16 are attenuated from the cones of molten glass formed at each orifice. The fibers are coated by size applicator 30 and gathered into strand 34 by gathering shoe 32. The strand is collected into package 40 on rotatably driven collet 38 on winder assembly 36. As the strand is being collected on the winder collet, it is reciprocated by traverse 42 for uniform collection of the strand on the collet.

The orifice projections depending from the feeder floor are in closely compacted relation to retain or maintain a layer of gas between the tips, adjacent the feeder floor. Since conventional

finshield units are not needed, the tips can be placed more closely together than in a conventional glass fiber forming bushing. The stream feeder tip density can be expressed in terms of the number of tips per square inch of feeder floor. One way of calculating this density is to divide the number of tips projecting from the feeder floor by the area of the feeder floor within the center line of the orifice pattern of the outside tips. In order to retain or maintain a quiescent layer of gas adjacent the tips, the bushing tip density should be within the range of from about 25 tips per square inch to about 150 tips per square inch. The tip density range which is preferred is from about 60 tips per square inch to about 80 tips per square inch.

The depending projections or tips are in close compacted relation to promote the retention of a layer of gas adjacent the feeder floor. This layer of gas generally extends from the feeder floor to the exit end of the orificed projections. This layer of gas is heated by the bushing and serves to insulate the bushing and its tips from the ambient environment in the forming room. This reduces the heat loss from the bushing and tends to make the glass fiber forming operation more stable. As will be discussed in more detail below, this layer of gas is generally a quiescent layer of gas which is not substantially disturbed during the fiber forming operation.

To control the glass fiber forming environment, gas blower means 20 is provided. As shown, the gas blower 20 comprises gas inlet 26, chamber 22 and a plurality of gas exit tubes or nozzles 24 arranged in two parallel rows and a row of exit orifices therebetween. The gas blower is positioned below the bushing and can be located a distance of from about three inches to about twelve inches below the bushing with a distance of from about eight inches to about ten inches being preferred. The gas can be directed upwardly at an angle of from about 80° to about 45° from the horizontal with a range of about 55° to about 50° being preferred. Gases such as, for example, air, carbon dioxide, nitrogen or mixtures thereof can be employed.

As shown, air is directed transversely from one side of the cones of glass and the bushing. However, any mechanical arrangement that directs cooling air or other gas upwardly into contact with the cones of glass at a velocity and in an amount to convey from the cones of glass sufficient heat to render the glass of the cones attenuable to fibers without appreciably disturbing the layer of gas at the region of the depending projections is satisfactory for use in this invention. A single nozzle, other multiple nozzle arrangements or a nozzle with a slit can be used. Deflector plates which deflect air to an upward path can also be employed. While introduction of the upwardly moving air from one side of the tipped bushing is entirely satisfactory and is preferred, the air can, if desired, be introduced from two or more sides of the bushing.

The air volumes and rates to be employed may

readily be determined by the routineer and will depend on such factors as bushing size, number of tips, tip density, glass throughput per tip, nozzle type and size, nozzle location and the like. Air can be supplied to the blower at a rate of 1000 standard cubic feet per hour to about 15,000, or more, standard cubic feet per hour to be directed upwardly into contact with the cones of glass to render the glass of the cones attenuable to fibers without substantially disturbing the relatively stagnant layer of air adjacent the bushing floor. The gas does not impinge on the feeder floor to essentially eliminate gas adjacent the feeder floor. Also, the layer of gas is not completely removed from the feeder floor by the gas directed upwardly.

Fig. 3 shows a portion of the bushing floor in more detail. Bushing 10 is provided with a plurality of tips 12 projecting from the feeder floor. The tips have an inside diameter 60 in the range about 0.04 inch to about 0.09 inch. In a preferred embodiment the inside diameter of the orificed projections is in the range of about 0.045 inch to about 0.055 inch. The depending projections can vary in length in the range of about 0.04 inch to about 0.15 inch. In a preferred embodiment, the tip length is in the range of about 0.06 inch to about 0.07 inch. The layer of gas 50 is shown extending from the feeder floor to the end of the orificed projections. It is within the scope of the invention that the thickness of this layer of gas can be somewhat larger or smaller than the length of the downwardly pending tip. This layer of gas is relatively stagnant as compared to the gas in the glass cone and fiber region of the glass fiber forming operation.

The gas from a nozzle 20 is projected up into the bushing area and is illustrated by zone 52. The gas directed upwardly into contact with cones 14 does not substantially disturb the layer of gas adjacent the feeder floor. As compared to the amount of air movement and the velocity of the air in zone 52, the air in layer 50 is relatively stagnant or quiescent. Any movement in this quiescent layer is substantially less than that of the active layer of air (having a similar thickness) below the ends of the tips (in the cone region).

The viscosity and temperature of the glass in cone 14 is controlled by the cooling air in zone 52. If the cone becomes too small, the stress in the glass in the cone becomes so large that fiber forming will be interrupted. If the cone becomes too large, glass will begin pumping through the tip in an uncontrolled manner and fiber forming will be interrupted. Thus, it is critical that the cone projecting from the orificed projection be controlled for a stable fiber forming operation. With a bushing having tips with inside hole diameters in the range of from about 0.04 inch to about 0.09 inch, cone lengths, that is, the cones which are visible to the naked eye as being red-hot and projecting down from the exit ends of the orificed projections, are controlled to be in the range of from about 0.015 inch to about 0.7 inch. For bushings having tips with inside diameters in

the range of about 0.045 inch to about 0.055 inch, the visible, red-hot, portion of each glass cone is controlled by the cooling air in zone 52 to have a length in the range of about 0.03 inch to about 0.09 inch. The cooling air in zone 52 controls the glass cones projecting from the orifice projections and the control can be defined in terms of the draw-down ratio which is equal to the inside hole diameter of the orificed projection divided by the length of the visible red-hot portion of the glass cone projecting from the orifice projection. The cooling air in zone 52 should be controlled to provide a draw-down ratio in the range of about 3 to about 0.13. In a preferred embodiment, the draw-down ratio is maintained with the range of about 1.5 to 0.5.

The following examples are included for illustrative purposes only and are not intended to limit the scope of the invention.

85 Example 1

In this example, a bushing having 275 tips was used. Each tip had an inside hole diameter of 0.046 inch and a tip length of 0.05 inch. The bushing had a tip density of 63 tips per square inch. Fibers were successfully drawn in stable operation and filament separation was maintained when air was directed upwardly from a blower to the cone region without disturbing the relatively quiescent zone of air adjacent the bushing floor. The air was directed upwardly into contact with the cones of glass by a blower having a row of six discharge tubes (each tube being about two inches in length and about one half inch in diameter) connected to a common discharge plenum. Air was supplied to the plenum in an amount within the range of from about 1200 standard cubic feet per hour to about 2200 standard cubic feet per hour, with a rate of about 1800 standard cubic feet per hour being preferred. The upwardly directed air controlled the visible glass cones projecting from the tips to a length within the range of from about 0.03 inch to about 0.09 inch.

110 Example 2

In this example, a bushing having 482 tips was used. Each tip had an inside hole diameter of 0.058 inch and a length of 0.120 inch. The bushing had a tip density of 110 tips per square inch. Fibers were successfully drawn in stable operation and filament separation was maintained when air was directed upwardly from a blower to the cone region without disturbing the relatively quiescent zone of air adjacent the bushing floor. The air was discharged upwardly into contact with the cones of glass by a blower having a row of six discharge tubes (each tube being about two inches in length and about one half inch in diameter) connected to a common discharge plenum. Air was supplied to the plenum in an amount within the range of from about 1200 standard cubic feet per hour to about 2000 standard cubic feet per hour, with a rate of about 1600—1700 standard cubic feet per hour being

preferred. The upwardly directed air controlled the visible glass cones projecting from the tips to a length within the range of from about 0.03 inch to about 0.12 inch.

5 Example 3

In this example, a bushing having 483 tips was used. Each tip had an inside hole diameter of 0.043 inch and a length of 0.055 inch. The bushing had a tip density of 110 tips per square inch. Fibers were successfully drawn in stable operation and filament separation was maintained when air was directed upwardly from a blower to the cone region without disturbing the relatively quiescent zone of air adjacent the bushing floor. The air was discharged upwardly into contact with the cones of glass by a blower having a row of six discharge tubes (each tube being about two inches in length and about one half inch in diameter) connected to a common discharge plenum. Air was supplied to the plenum in an amount within the range of from about 1200 standard cubic feet per hour to about 2500 standard cubic feet per hour with a rate of about 1700—1900 standard cubic feet per hour being preferred. The upwardly directed air controlled the visible glass cones projecting from the tips to a length within the range of from about 0.03 inch to about 0.09 inch.

30 Example 4

In this example, a bushing having 4,024 tips was used. Each tip had an inside hole diameter of 0.049 inch and a length of 0.065 inch. The bushing had a tip density of 74 tips per square inch. Fibers were successfully drawn in stable operation and filament separation was maintained when air was directed upwardly from a blower to the cone region without disturbing the relatively quiescent zone of air adjacent the bushing floor. The air was discharged upwardly into contact with the cones of glass by a blower having two rows of tubes (each tube being about four inches in length and about three eighths of an inch in diameter) and a row of orifices between the two rows of tubes connected to a common discharge plenum. Air was supplied to the plenum in an amount within the range of from about 4000 standard cubic feet per hour to about 15,000 standard cubic feet per hour with a rate of about 9000 standard cubic feet per hour being preferred. The upwardly directed air controlled the visible glass cones projecting from the tips to a length within the range of from about 0.03 inch to about 0.09 inch. The upwardly directed air did not impinge on the feeder floor to essentially eliminate stagnant gas adjacent the feeder floor. Also, the upwardly directed air did not completely remove the relatively quiescent zone of air adjacent the bushing floor.

Having described the invention in detail, it will be understood that such specifications are given for the sake of explanation. Various modifications and substitutions other than those cited may be

made without departing from the scope of the invention as defined in the following claims.

65 Claims

1. A method of forming glass fibers from orificed projections of a stream feeder comprising:
 - a) drawing streams of glass from the orificed projections while maintaining a quiescent layer of gas in contact with the orificed projections, the streams of glass forming cones of glass at the discharge end of the orificed projections; and
 - b) directing a gas upwardly into contact with the cones of glass proximate the orificed projections to cool said glass in the absence of any substantial disturbance of said layer of gas.
2. A method of forming glass fibers comprising:
 - a) flowing streams of glass from a stream feeder through orificed projections depending from the feeder floor;
 - b) attenuating fibers from cones of molten glass formed at each orifice, the orificed projections being in close compacted relation to promote the retention of a thermally insulating layer of heated air adjacent the feeder floor; and
 - c) directing gas upwardly into contact with the cones of glass at a velocity and in an amount to convey from the cones of glass sufficient heat to control the temperature of the glass of the cones to render the glass attenuable to fibers without appreciably affecting the layer of heated air.
3. A method according to claim 1 or claim 2 wherein during attenuation of fibers, the streams of glass form a cone of glass at the discharge end of each orificed projection and the gas controls a visible, red-hot, portion of each glass cone such that the visible, red-hot, portion of each glass cone projects from its orificed projection an amount within the range of from about 0.015 inch to about 0.7 inch.
4. A method according to claim 3 wherein the range is from about 0.03 inch to about 0.09 inch.
5. A method according to any preceding claim wherein during attenuation of fibers, the streams of glass from a cone of glass at the discharge end of each the orificed projection and the gas controls the cones of glass such that the cones of glass have a draw-down ratio within the range of from about 3 to about 0.13.
6. A method according to claim 5 wherein the range is from about 1.5 to about 0.5.
7. A method according to any preceding claim wherein the gas is directed transversely from one side of the cones of glass.
8. A method according to any preceding claim wherein the gas is directed in a plurality of streams.
9. A method according to any preceding claim wherein the directed gas comprises air, carbon dioxide or nitrogen.
10. A method according to any preceding claim wherein the said thermal insulating layer of gas contacts the feeder floor and extending to a depth substantially equal to the vertical extension

of the tip, said cones being exposed to the cooling action of the upwardly directed gas.

11. A method according to any preceding claim wherein no finshields or equivalent
5 conductive cooling device is utilised in the region of the tips.

12. A method according to any preceding claim wherein there are from 25 to 150 tips per square inch of feeder floor.

13. A method according to claim 12 wherein
10 there are from 60 to 80 tips per square inch of feeder floor.

14. Apparatus for forming glass fibers comprising:

15 a) a stream feeder having orificed projections in its floor and means for drawing streams of glass issuing from the orificed projections into fibers with the streams of glass forming cones of glass at the discharge end of the orificed
20 projections, wherein the orificed projections are in close compacted formation to promote the retention of a thermally insulating layer of gas adjacent the feeder floor; and

25 b) means for directing gas upwardly into contact with the cones of glass at a velocity and in an amount to convey from the cones of glass sufficient heat to render the glass of the cones attenuable to fibers while leaving the thermally insulating layer of gas substantially undisturbed.

30 15. Apparatus for forming glass fibers comprising:

a) means for flowing streams of glass from a stream feeder through orificed projections depending from the feeder floor;

35 b) means for attenuating fibers from cones of molten glass formed at each orifice, the orificed projections being in close compacted relation to promote the retention of a layer of heated air adjacent the feeder floor; and

40 c) means for directing gas upwardly into

contact with the cones of glass at a velocity and in an amount to convey from the cones of glass sufficient heat to control the temperature of the glass of the cones to render the glass attenuable to fibers without appreciably affecting the layer of heat air at the region of the orificed projections.

45 16. Apparatus according to claim 14 of claim 15 wherein the feeder floor has from 25 orificed projections per square inch to 150 orificed
50 projections per square inch.

17. Apparatus according to claim 16 wherein the feeder floor has from 60 orificed projections per square inch to 80 orificed projections per square inch.

55 18. Apparatus according to any of claims 14 to 17 wherein the orificed projections have a length within the range of from 0.04 inch to 0.15 inch.

60 19. Apparatus according to claim 18 wherein the orificed projections have a length within the range of from 0.06 inch to 0.70 inch.

20. Apparatus according to any of claims 14 to 19 wherein the orifice projections have an inside diameter within the range of from 0.04 inch to 0.09 inch.

65 21. Apparatus according to claim 20 wherein the orificed projections have an inside diameter within the range of from about 0.045 inch to about 0.055 inch.

70 22. Apparatus according to any of claims 14 to 21 wherein the means for directing gas upwardly is adapted to direct the gas transversely from one side of the cones of glass.

75 23. Apparatus according to any of claims 14 to 22 wherein no finshields or equivalent conductive cooling device is utilised in the region of the tips.

24. A method according to claim 1 or claim 2 substantially as hereinbefore disclosed.

80 25. Apparatus according to claim 14 or claim 15 substantially as described herein with reference to the accompanying drawings.