April 11, 1961 C. F. SCHROEDER 2,978,744

METHOD AND APPARATUS FOR FORMING FIBERS

Filed Sept. 9, 1955 6 Sheets-Sheet 1

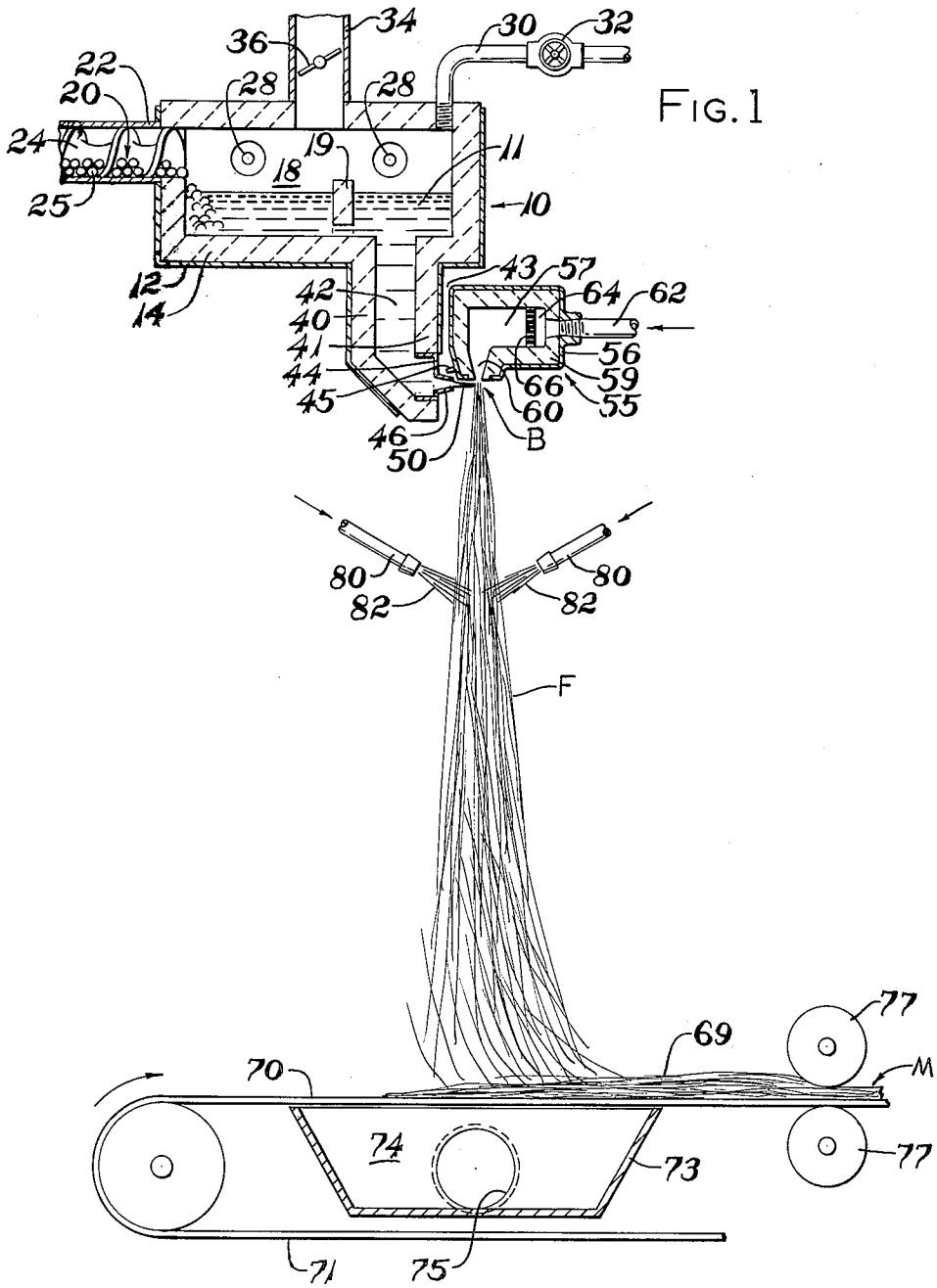


FIG. 1

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METHOD AND APPARATUS FOR FORMING FIBERS

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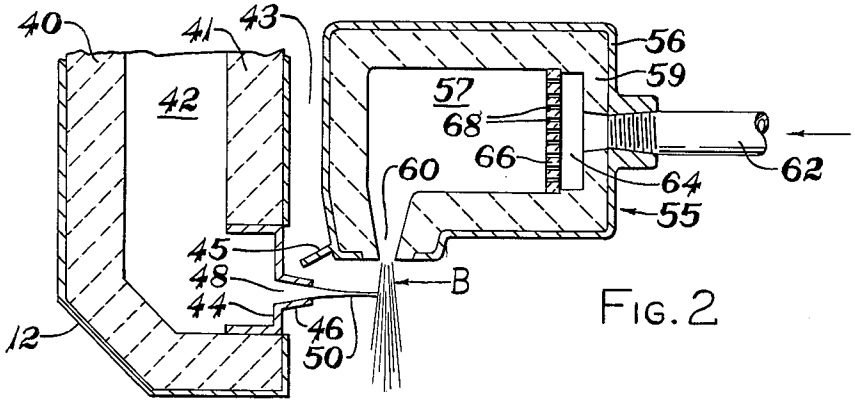


FIG. 2

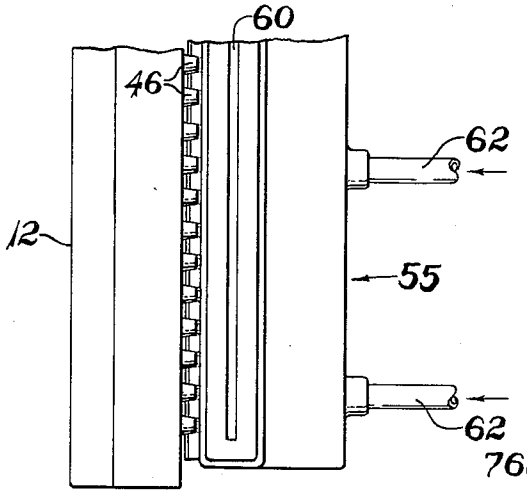


FIG. 3

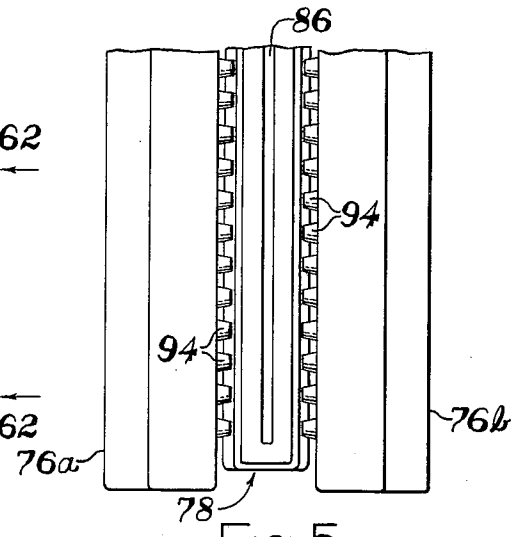


FIG. 5

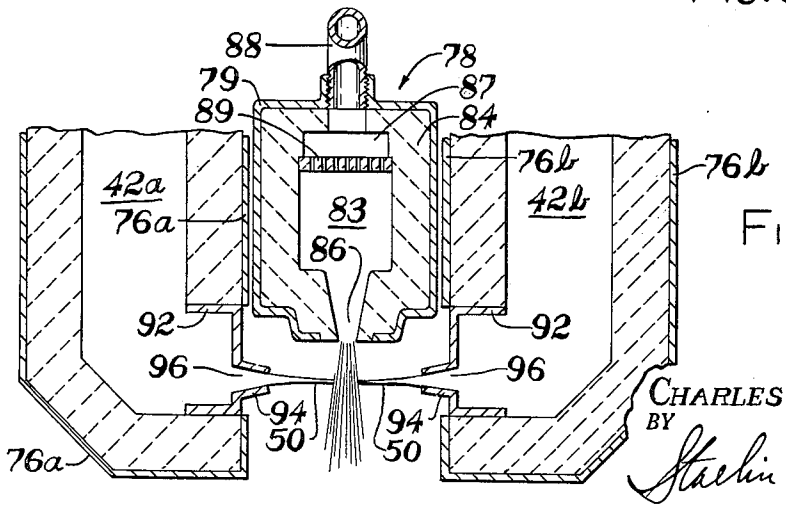


FIG. 4

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METHOD AND APPARATUS FOR FORMING FIBERS

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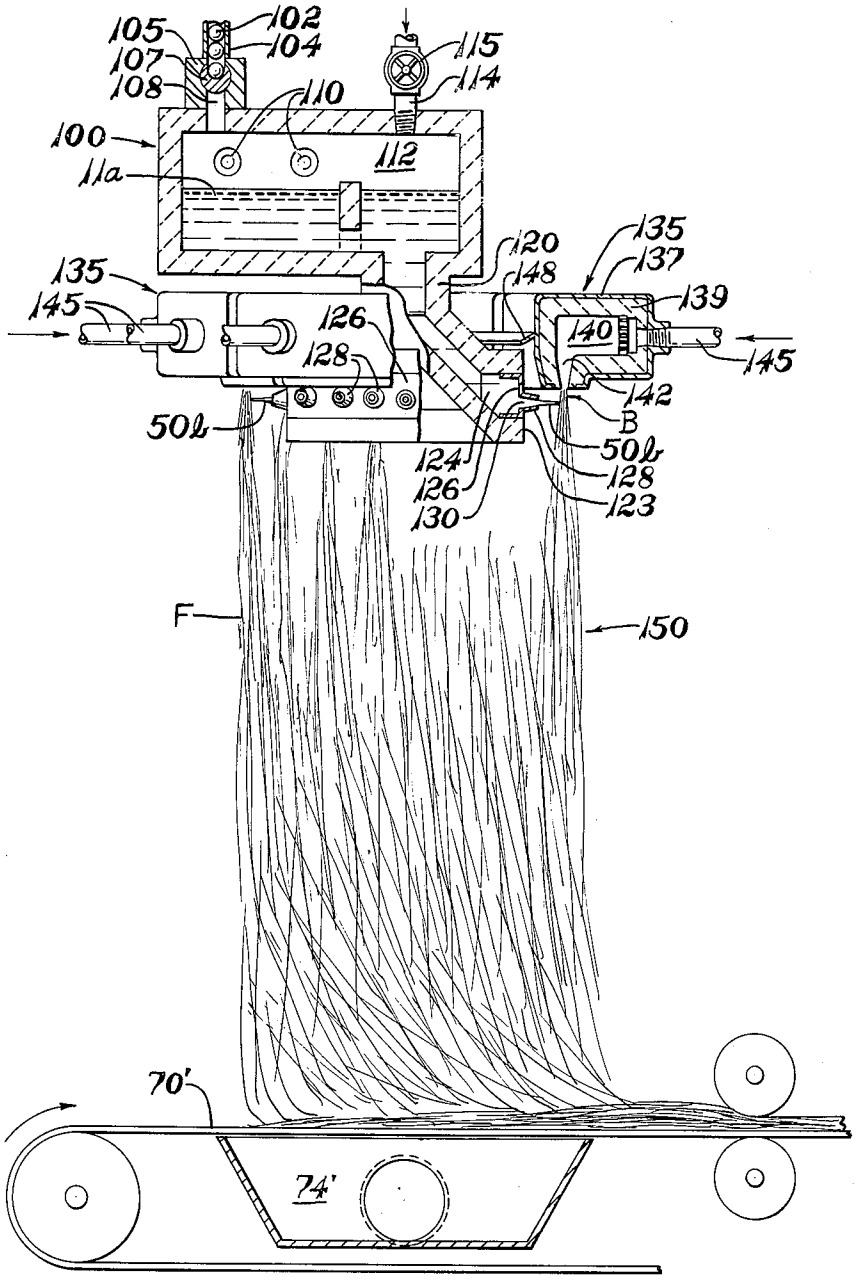


FIG. 6

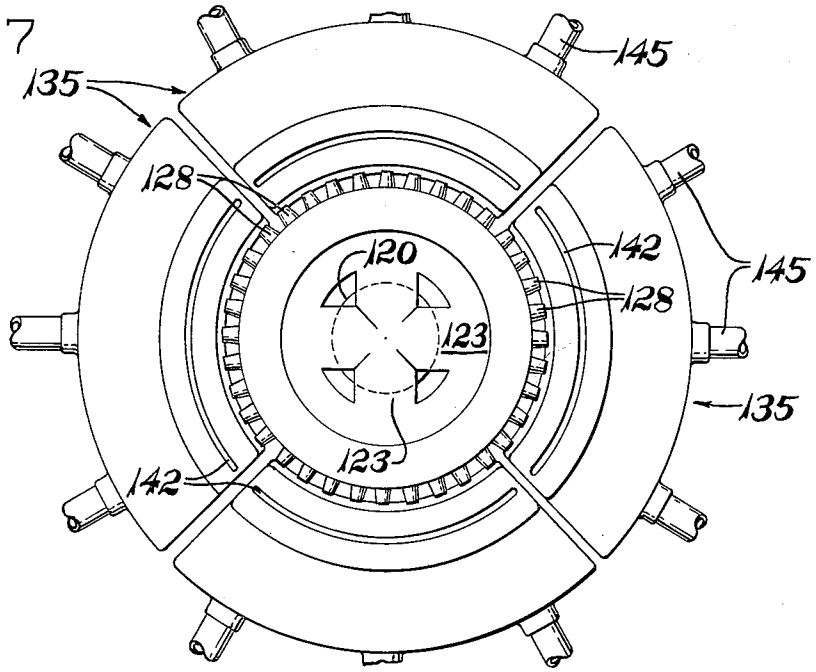
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METHOD AND APPARATUS FOR FORMING FIBERS

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FIG. 7



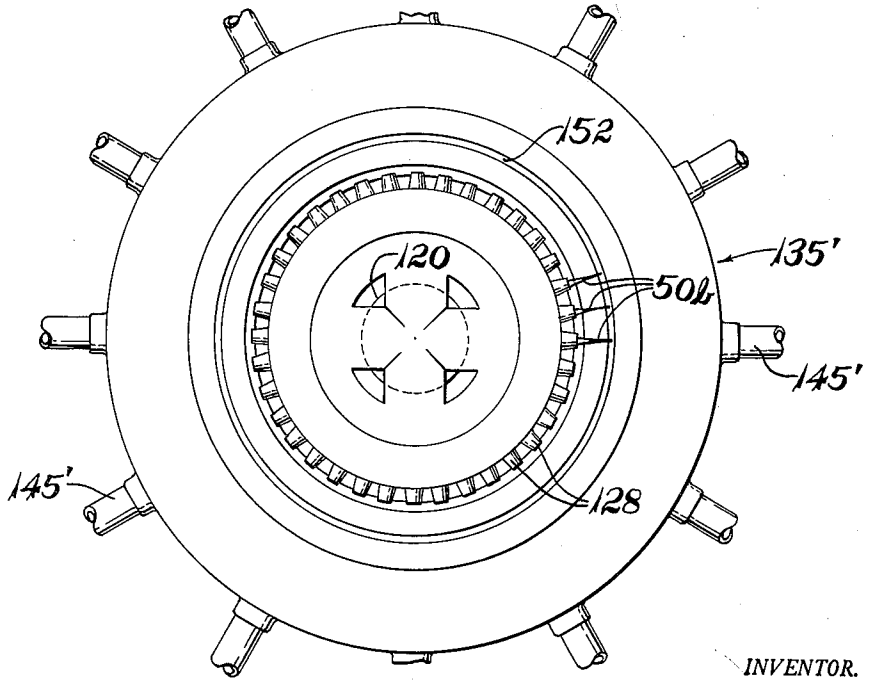


FIG. 8

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METHOD AND APPARATUS FOR FORMING FIBERS

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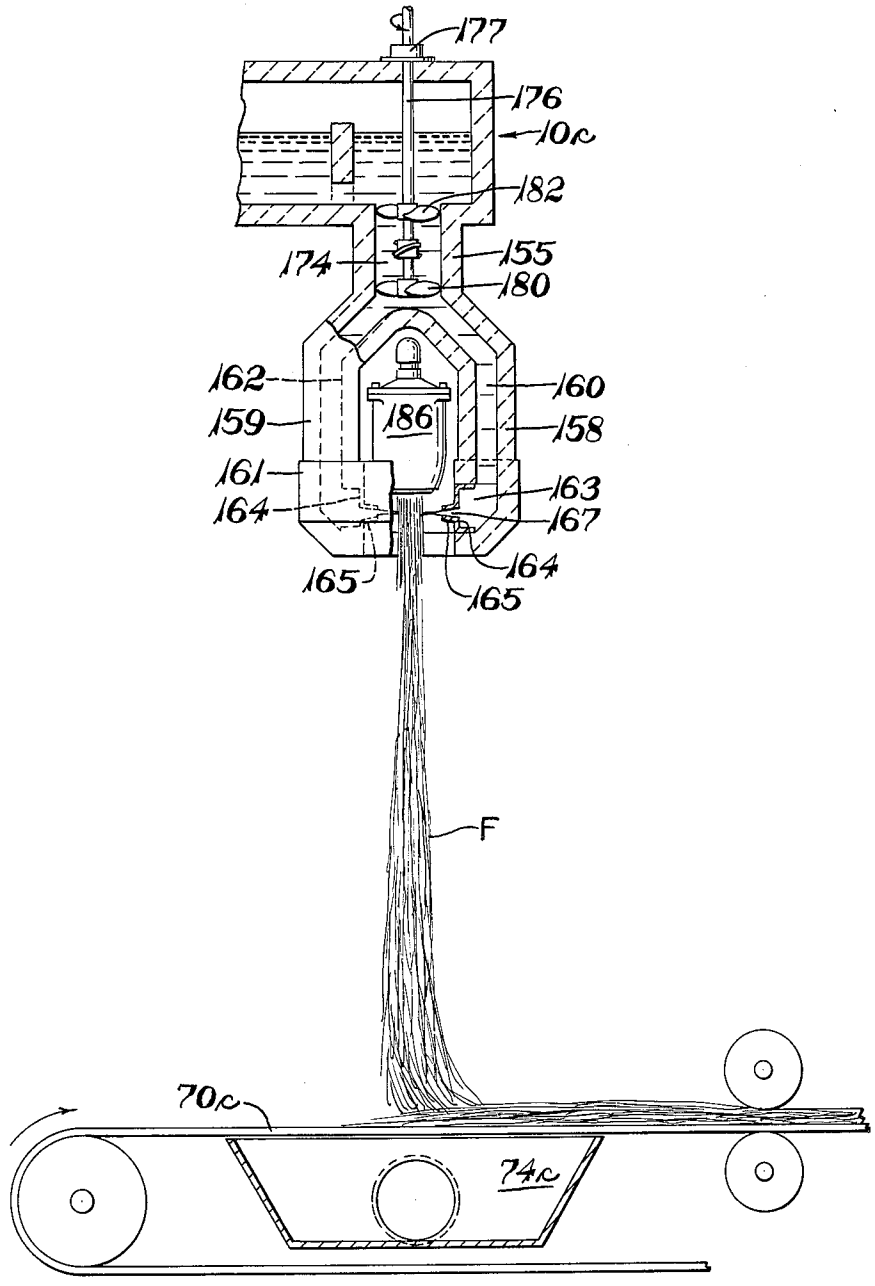


FIG. 9

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METHOD AND APPARATUS FOR FORMING FIBERS

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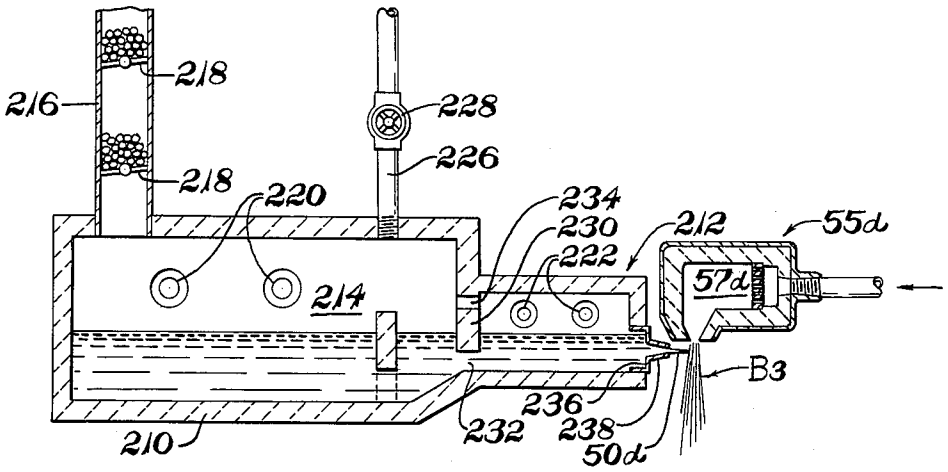


FIG. 12

FIG. 11

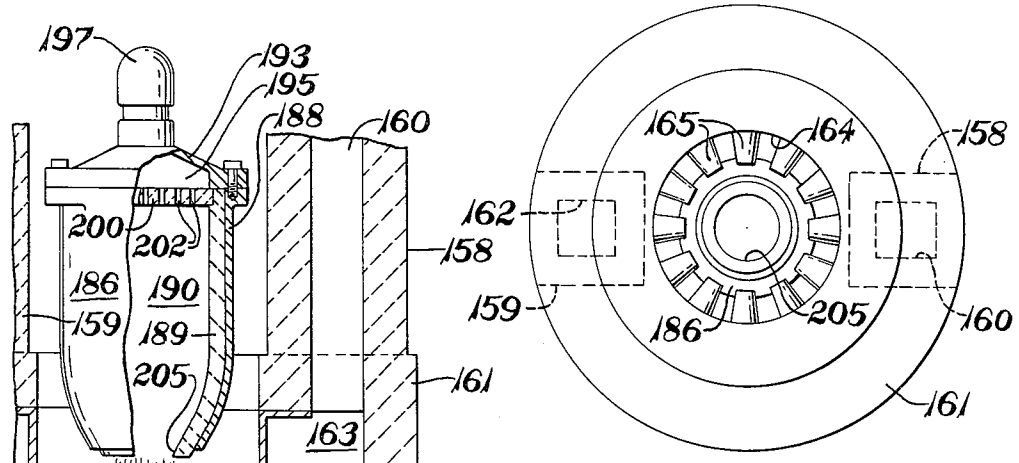


FIG. 10

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United States Patent Office 2,978,744 Patented Apr. 11, 1961

2,978,744

METHOD AND APPARATUS FOR FORMING FIBERS

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Filed Sept. 9, 1955, Ser. No. 533,289

16 Claims. (Cl. 18—2.5)

This invention relates to method and apparatus for forming fibers and more especially to a method and apparatus for forming fine fibers by direct engagement of gaseous attenuating blasts with fine streams or primaries of molten fiber-forming mineral material.

Fibers have heretofore been formed by several methods utilizing blasts of gases for attenuating heat-softenable mineral material to fibers. One of the earlier methods of forming slag or mineral wool comprised flowing a comparatively large stream of molten slag or argillaceous rock from a furnace and directing a jet of steam against the stream, atomizing the stream to form relatively coarse fibers commercially known as slag or rock wool. The fibers made by this method were not only very coarse but the end product contained a major proportion of unfiberized material in the form of pellets or shot.

Glass wool has been manufactured in substantial commercial quantities by flowing a plurality of streams vertically from a forehearth and directing steam or compressed air blasts downwardly in the general direction of flow of the streams and engaging the streams to form fibers.

Another method that has been used involves forming substantially solid primary filaments from streams of glass or other mineral material and feeding the primary filaments in solid form endwise into an intensely hot gaseous blast whereby the heat of the blast softens the filaments and the velocity of the gases of the blast attenuates the softened material to fibers.

In such prior processes as have been used commercially, the streams of molten material have been delivered by gravity into gaseous attenuating mediums, or the streams have first been drawn into solid primary filaments and the solid filaments delivered into an intensely hot blast.

More recent developments include forming a body of molten mineral material into a plurality of radially projected linear bodies by centrifugal forces and engaging the projected bodies with a gaseous blast to form the radially moving bodies into fine fibers. Such method or process involves the use of one or more elements rotating at high speeds and hence requires precision equipment for its successful operation. This method of fiber formation is highly efficient and produces very fine fibers. It appears that the production of extremely fine fibers from the use of centrifugal units is attributable to the use of comparatively fine primaries or streams of the material delivered to the attenuating blast. The controlled or substantially constant pressure exerted by centrifugal forces of rotation of an element or spinner effects extrusion of the fiber-forming material into extremely fine elongated bodies of lesser diameters than primaries or elongated bodies obtained from streams of glass motivated solely by gravity.

The present invention embraces the provision of a method and apparatus for forming fine streams, elongated

bodies or primaries of fiber-forming mineral material by regulated or controlled pressure extrusion of material under static pressure sufficient to project the streams or primaries in substantially horizontal paths, and engaging the streams or primaries by a gaseous attenuating blast moving in a direction substantially normal to the paths of the extruded streams or primaries to form the same into fine fibers.

An object of the invention resides in pressurizing a receptacle, furnace or forehearth containing molten fiber-forming material and extruding the material in a manner to form a plurality of fine streams or primaries and engaging the streams or primaries by a high velocity gaseous blast to attenuate the streams or primaries to fibers.

Another object of the invention resides in the provision of forehearth and feeder means maintained under pressure whereby a large number of minute streams or bodies of glass or other heat-softenable material may be projected at controlled flow rates from opposed directions into an attenuating blast formed of burned gases of combustion at temperatures well above the attenuating temperature of the glass whereby the streams or bodies are attenuated into fine fibers.

Another object of the invention resides in the provision of a method and apparatus for attenuating fibers wherein molten fiber-forming material is extruded under pressure under controlled conditions through small openings forming fine primary filaments or bodies which are engaged by a high velocity gaseous blast to form fibers without the use of moving or rotating elements or mechanism.

Still another object of the invention is the provision of a method and apparatus of forming fibers wherein a comparatively large number of pressure extruded bodies of fiber-forming material are delivered into an attenuating blast wherein comparatively large quantities of fiber-forming material are converted to fine fibers with a minimum expenditude of attenuating energy.

Further objects and advantages are within the scope of this invention such as relate to the arrangement, operation and function of the related elements of the structure, to various details of construction and to combinations of parts, elements per se, and to economies of manufacture and numerous other features as will be apparent from a consideration of the specification and drawing of a form of the invention, which may be preferred, in which:

Figure 1 is a vertical sectional view showing a form of apparatus for carrying out the method of the invention;

Figure 2 is an enlarged detail sectional view of a portion of the apparatus shown in Figure 1;

Figure 3 is a bottom plan view of the arrangement shown in Figure 2;

Figure 4 is a vertical sectional view illustrating another form of apparatus for carrying out the method of the invention;

Figure 5 is a bottom plan view of the arrangement shown in Figure 4;

Figure 6 is an elevational sectional view with certain parts shown in section of another form of apparatus for carrying out the method of the invention;

Figure 7 is a bottom plan view of the filament and fiber-forming apparatus shown in Figure 6;

Figure 8 is a view similar to Figure 7 illustrating an arrangement for delivering an annular attenuating blast;

Figure 9 is an elevational view with certain parts shown in section of another form of apparatus for carrying out the method of the invention;

Figure 10 is an enlarged sectional view of a portion of the apparatus shown in Figure 9;

Figure 11 is a bottom plan view of the filament and fiber-forming apparatus shown in Figure 9, and

Figure 12 is a sectional view of a furnace, forehearth and feeder construction for delivering fiber forming material under pressure to an attenuating blast.

The forms of apparatus illustrated are especially adaptable for forming fine primary filaments, streams or elongated bodies of molten glass which are projected into an attenuating blast and thereby attenuated to very fine fibers. It is to be understood that the method and apparatus of the invention may be used for forming primary filaments and fibers from other heat-softenable materials such as fusible rock, slag or other thermoplastic or wherever the method and arrangement may be found to have utility.

Referring to the drawings in detail, Figures 1 through 3 illustrate one form of apparatus for carrying out the method of the invention. Numeral **10** designates a melting furnace, tank or receptacle in which is maintained a supply of molten fiber forming material **11** such as glass, slag, fusible rock or other heat softenable mineral material from which fibers may be formed by attenuation.

The furnace or receptacle **10** may be formed with a metal casing **12** which is lined with suitable refractory **14** capable of withstanding the high temperatures of the molten glass or other fiber-forming material.

The furnace or receptacle **10** forms a confined zone or chamber **18** containing the supply of fiber forming material and pressure is impressed in the chamber **18** so that the supply of molten glass or other material is maintained under a static pressure in order to facilitate satisfactory extrusion of the material through comparatively small orifices. A means is provided for feeding raw glass batch **20** or other composition of fiber-forming material to be introduced into the chamber **18** and therein reduced to a molten state or condition.

As shown in Figure 1, a cylindrical tube **22** extends from the furnace **10** and disposed interiorly of the tube **22** is a material feeding means in the form of a screw or member **24** which is snugly but rotatably disposed in the tube **22** to prevent reduction in pressure within the chamber **18**. It is to be understood that other forms of means for introducing raw batch into the furnace may be employed if desired. The batch feeding means or screw **24** shown in the embodiment in Figure 1 is driven by a motor (not shown) or other suitable means at a speed to deliver or convey the batch **25** into the furnace **10** substantially at the rate that the molten material is extruded from the furnace in a manner hereinafter described.

A wall or dam **19** in the furnace having an opening through which the glass flows assists in refining the molten glass. The batch, after delivery into the chamber **18**, may be rendered molten by the application of heat, and burners or heating means **28** may be utilized for this purpose. The burners or heating means **28** may be connected with a source (not shown) of combustible mixture such as fuel gas and air delivered to the burners under pressure, the combustible mixture being ignited and burned within the chamber **18**.

The pressure of the burning gases and products of combustion may be utilized to pressurize the chamber **18** or pressure may be impressed in chamber **18** by the introduction of other gases through a duct or tube such as tube **30**. A regulating valve **32** which may be manually controlled or an automatic pressure regulator may be employed to regulate the flow of gases under pressure into the chamber **18**.

When burners **28** are utilized to deliver combustible mixture into the chamber **18** to be burned therein, a vent means may be provided for the chamber **18** equipped with a valve for maintaining the desired pressure in the chamber. In Figure 1 the upper wall of the furnace or receptacle **10** is provided with a vent tube **34** equipped with a valve **36** which may be manually or automatically controlled for maintaining a constant pressure in the chamber.

Figures 1, 2 and 3 illustrate an arrangement for projecting or extruding streams or primaries of the molten fiber forming material into an attenuating blast in which the molten streams or primaries are attenuated to fibers. Depending from the furnace **10** are walls **40** and **41** providing, in effect, a forehearth defining a passage, chamber or well **42** arranged to receive molten material from the supply **11** in the chamber **18**. The wall **41** of the passage is equipped with a feeder **44** which may be formed of high temperature resistant metal such as platinum rhodium, platinum iridium or other suitable metal or alloy capable of withstanding the high temperatures of the molten material.

The feeder **44** is formed with orifice means for exuding or extruding fine streams of molten fiber forming material contained in the passage or chamber **42**. In the embodiment illustrated in Figures 1, 2 and 3, the feeder **44** is formed with the plurality of tips, nozzles or projections **46**, each of which is formed with a small orifice or outlet **48** through which a stream **50** of molten fiber forming material is delivered or extruded under pressure.

The streams **50**, also referred to herein as primaries, primary filaments or elongated bodies, are projected in a substantially horizontal direction or plane as shown in Figures 1 and 2. A current of electrical energy may be delivered through the metal feeder **44** to control or regulate the viscosity of the molten material in the feeder so that the material may be extruded at a viscosity to provide primaries most satisfactory for attenuation to fibers.

The streams **50**, under the influence of the substantially constant static pressure in the chamber **18**, are projected in a substantially rectilinear direction for some distance beyond the outlets **48** in the tips **46**. In the present invention the streams or primaries **50** are delivered endwise into an attenuating blast. As shown in Figures 1 through 3 there is provided a burner **55** having a metal casing **56**, the burner being formed with a combustion chamber or confined zone **57** in which a combustible mixture is adapted to be substantially completely burned. The chamber **57** is defined by walls **59** of suitable refractory capable of withstanding the high temperature of the burning gases in the chamber, the temperature of the gases being 3000° F. or higher.

A lower wall of the chamber **57** is provided with a restricted orifice or outlet **60** which, as shown in Figure 3, is of elongated rectangular character. The burner **55** is connected with a tube **62**, the latter being connected with supply of combustible mixture such as fuel gas and air. Any suitable fuel gas may be used such as methane, ethane or propane, and the combustible mixture is delivered by the tube or duct **62** into a manifold chamber or passage **64**. A rear wall **66** of the chamber **57** adjacent the mixture inlet or manifold chamber **64** is formed with plurality small perforations or passages **68** through which the mixture is conveyed into the chamber **57**.

The perforated wall **66** forms a fire or protective screen to avoid or prevent preignition of the mixture in the passage **64** or the duct **62**. The fuel and air mixture may be delivered into the chamber **57** under a comparative low pressure of from three to 10 lbs. p.s.i. The combustible mixture is ignited in the chamber **57** and is substantially completely burned within the chamber or confined zone.

The burning gases undergo great expansion in the chamber **57**, the walls of the chamber being heated to incandescent which accelerates flame propagation or combustion taking place within the chamber. The burned gases are discharged through the restricted orifice or outlet **60** as an intensely hot high velocity gaseous blast

of a temperature above the attenuating temperature of the fiber forming material. As shown in Figures 1 and 2, the blast B from the orifice 60 is projected downwardly in a direction substantially normal to the endwise delivery of the primaries or streams 50 into the blast.

The streams or primaries 50 are attenuated by the blast B to fine fibers F. While the primaries or streams 50 are in a flowable condition as they enter the blast, there may be some chilling or cooling of the streams and increase in viscosity by the air flow induced by the blast through the space 43 between a wall of the burner and wall 41 of the well 42. The increase in viscosity or thickened condition of the streams entering the attenuating blast B provides in each stream a nub or inertia zone from which fibers may be drawn, the heat of the gases of the blast elevating the temperature of the material of the streams whereby the extremities of the streams in the blast are softened or conditioned so that they are drawn by the blast into long fine fibers.

With the arrangement above described, fine streams or primaries 50 may be delivered into the high temperature blast B so that the extremely fine fibers of a diameter of two microns or less may be economically produced in commercial quantities. While it is advantageous to utilize a blast of a temperature above the attenuating temperature of the fiber forming material in order to form fine fibers, it is to be understood that the streams or primaries 50 may be delivered into a blast of steam or compressed air moving in a direction normal or perpendicular to the paths of the primaries projected from the outlets or orifice 48. However, fibers attenuated by steam or air blasts are usually not as fine as those produced by the hot blast method.

The newly formed fibers F entrained in the blast move downwardly as shown in Figure 1 and may be collected in a mass 69 upon the upper flight 70 of an endless foraminous conveyor 71, the flight 70 moving in a right-hand direction as viewed in Figure 1. A box or receptacle 73 may be disposed beneath the upper flight 70 of the conveyor in the path of the descending fibers F providing a chamber 74. A duct 75 connects the chamber 74 with a suction blower (not shown) for establishing a suction or subatmospheric pressure in chamber 74 to assist in collecting the fibers upon the conveyor flight 70 and to convey away spent gases of the attenuating blast. The mass 69 of fibers may be passed between compression or sizing rolls 77 for predetermining the thickness of the mat M formed from the fibers.

It may be desirable to apply a binder or other coating material to the newly formed fibers in order to impart mass integrity to the end product. As shown in Figure 1, applicators 80 may be disposed adjacent opposite sides of the descending fibers F for projecting binder 82 or other fiber coating material on to the fibers. The binder may be of any type but a thermo-setting material is preferred such as phenol formaldehyde or urea formaldehyde. The mat of fibers treated with the bonding agent or material may be conveyed through an oven or curing zone to set the binder in the fibrous mat.

By regulating the air flow along the blast, a measure of control may be had over the condition of viscosity of the streams 50. A control over the amount of air admitted along the blast through the space 43 may be provided in the form of a baffle or plate 45 which may extend across the space 43 to a desired extent depending upon the amount of air to be admitted along the blast to control the extent of chilling or cooling of the streams 50. The baffle 45 may be secured to the casing wall of the burner 55 and may be made adjustable if desired.

Figures 4 and 5 illustrate modified form of apparatus for forming heat-softenable mineral material to fibers. In this form of apparatus, means is provided at each side of a gaseous blast for projecting or extruding streams of molten mineral material such as glass into the blast. The arrangement shown in Figure 4 may be utilized with a furnace or melting receptacle of the character shown in Figure 1 provided with a second means for delivering an additional group of streams into an attenuating blast. Depending from the furnace or melting receptacle is a forehearth arrangement including two passages, wells or chambers 42*a* and 42*b* which are adapted to receive molten glass or other molten mineral material from the melting furnace. The walls defining the passages 42*a* and 42*b* are formed of refractory capable of withstanding the intense heat of the molten material. The walls of the passage 42*a* may be enclosed by a metal casing 76*a* and the walls defining the passage 42*b* may be enclosed in a metal casing 76*b*.

The adjacent walls of the casings 76*a* and 76*b* are spaced to accommodate a blast producing means or internal combustion burner 78. Burner 78 is similar to the burner 55 and is inclusive of a metal casing 79 in which is formed a combustion zone of chamber 83 defined by walls 84 of refractory. The lower wall of the chamber 83 is formed with a restricted outlet or orifice 86 which is of elongated character as shown in Figure 5.

The burner 78 is connected with a tube or pipe 88 adapted to convey a combustible mixture of fuel gas and air into the combustion chamber or confined zone 83. The rear wall 89 of the combustion chamber 83 is formed with a plurality of small openings or passages to convey the mixture into the chamber, the perforated wall providing a fire screen to prevent preignition of the mixture in the inlet 87 and the supply pipe 88.

The burner 78 is deposed between the downwardly extending material conveying passages or wells 42*a* and 42*b* as shown in Figure 4. A wall of each of the depending portions of the receptacle defining the chambers 42*a* and 42*b* is provided with a feeder or bushing 92 which may be made of metal or alloy capable of withstanding the intense heat of the molten material. Such alloys as platinum rhodium or platinum iridium have been found satisfactory for the purpose.

Each of the feeders 92 is formed with a plurality of tips, nozzles or projections 94 and each of the tips is provided with an orifice or outlet 96 through which molten material from the wells 42*a* and 42*b* is projected or exuded in a fine stream 50. The projections or tips 94 are disposed so as to project the streams 50 in substantially horizontal directions and endwise into the downwardly projected blast as shown in Figure 4.

The groups of projections 94 of the feeders are disposed in opposed relation whereby the streams 50 from the groups of tips are projected in opposite directions in entering the blast. As shown in Figure 5, each orifice 96 of one group is disposed in alignment with an orifice 96 in the opposite group, but it is to be understood that the orifices of one group may be disposed in staggered relation with respect to the orifices in the opposite group so that each stream of molten material may enter a different zone of the blast.

Through the arrangement shown in Figures 4 and 5, a large amount of molten material may be introduced into a single elongated blast projected through the slot or restricted orifice 86. The pressure impressed upon the supply of molten material is effective on the material in the wells 42*a* and 42*b* and feeders 92 to project the streams 50 endwise into the blast at a substantial velocity. As shown in Figure 4 the inner walls 76 of the well constructions are disposed in close relation to the side walls of the burner casing 79 in order to restrict the flow of induced air along the blast.

It is to be understood that the casings 76*a* and 76*b* may be spaced at greater distances from the burner wall and baffles or other means may be disposed between the burner walls and the casings 76*a* and 76*b* for restricting and controlling the flow of induced air along the blast. The induced air, as previously mentioned in connection

with the form of the apparatus shown in Figures 1 through 3, chills the streams **50** rendering them more viscous. Thus by restricting and controlling the induced air, the viscous condition of the streams or primaries **50** may be controlled and the streams or primaries delivered into the blast under optimum conditions to obtain the most efficient attenuation of the streams or primaries.

Figures 6 and 7 illustrate another form of apparatus for delivering streams or primaries of molten material in radial directions into a substantially annular gaseous attenuating blast. This arrangement is inclusive of a pressurized melting furnace, tank or receptacle **100** in which is contained a supply of molten fiber forming material **11***a*. In the melting furnace illustrated, the glass or other mineral fiber-forming material may be introduced into the furnace in the shape of preformed spheres or marbles **102**.

A tube **104** extending upwardly from the furnace contains a supply of glass marbles. A member **105** associated with the furnace **100** is provided with a rotary valve **107** adapted to successively deliver the marbles from the tube **104** through a passage **108** into the furnace without affecting the pressure in the melting chamber **112**. Heating means in the form of burners **110** are disposed in the chamber **112** for melting the marbles.

Pressure above atmospheric pressure is impressed in the chamber **112**. This may be accomplished by the pressure of the burning gases from the burners **110** which may be supplemented by gases under pressure introduced into the chamber through a pipe or duct **114**. A valve **115** is associated with a pipe **114** for controlling the flow of pressure gases into the closed pressurized chamber **112**.

The forehearth **120** in the embodiment illustrated depends from the furnace construction **100**. The forehearth **120** extends downwardly and outwardly in an annular formation providing an annularly shaped well **124**. A portion **123** is formed with an annularly shaped feeder **126**. The feeder **126** is fashioned with a plurality of outwardly and radially extending tips or projections **128** each of which is formed with an orifice **130** through which streams **50***b* are projected under the influence of superatmospheric pressure on the supply of glass or other material in the chamber **112**.

A substantially annular gaseous blast is provided adapted to engage the streams **50***b* to attenuate the streams to fibers. As shown in Figure 7, the blast establishing means is inclusive of four burners **135** each being shaped as a circular ring sector, which in assembled relation provide a substantially annular burner arrangement. Each of the burners **135** includes a metal casing **137**, the interior which is lined with refractory **139** shaped to define an internal combustion chamber or confined zone **140**.

A wall of each burner is formed with a restricted outlet or orifice means **142** of arcuate shape through which burned gases or products of combustion from the chamber **140** are discharged as a high velocity blast of a temperature above the attenuating temperature of the fiber forming material. A combustible mixture is delivered into the combustion chamber **140** of each burner through tubes **145** which are connected with a supply of combustible mixture such as fuel gas and air.

The mixture is burned in the chamber **140** under confined conditions, the burning gases undergoing great expansion attaining a temperature of 3000° F. or more before they are discharged at high velocities through the restricted orifice **142**. As shown in Figure 7, the several arcuately shaped orifices in effect provide a substantially annular blast. The annular blast emanating from the orifice means **142** of the burners engages the streams or primaries from the orifices **130** in a direction substantially normal to the flow of the streams from the annular feeder **126**.

The amount of air flow induced by the velocity of the gaseous blast may be controlled by an annular plate **148** disposed in the path of flow of air between the feeder **126** and the inner walls of the burner casings **137**. The width of the plate **148** and its position may be varied or adjusted to provide the desired restriction to the induced air flow. The streams **50***b* move radially in substantially horizontal directions under the influence of the pressure impressed on the molten material.

The attenuated fibers are entrained in the annular blast and are carried downwardly by the blast in the form of the circular cylindrically shaped beam or column **150** of fibers. The fibers of the beam may be collected upon an upper flight **70'** of a foraminous conveyor of the character shown in the Figure 1. A suction chamber **74'** is provided beneath the conveyor flight **70'** in order to assist in collecting the fibers on the conveyor and to carry away spent gases of the blast.

Figure 8 is a bottom plan view of an arrangement simliar to that shown in Figure 7 with the burner construction **135'** formed as a continuous annulus. The burner **135'** is formed with a continuous annular-shaped combustion chamber from which burned gases or products of combustion are discharged through a continuous annularly shaped restricted orifice **152**. Streams of molten fiber-forming material are delivered through the orifices formed in projections **128** in the manner shown in Figure 6. Combustible mixture is introduced into the combustion chamber of the burner **135'** through pipes **145'** connected with a supply of fuel gas and air. The streams **50***b* are attenuated by the annular blast from the orifice **152** in the same manner described in connection with Figures 6 and 7.

Figure 9 is a view similar to Figure 1 illustrating another form of apparatus for carrying on the method of the invention. The melting furnace **10***c* in which glass batch is adapted to be melted is arranged to receive glass batch through the use of means such as those illustrated in Figures 1 and 6. The furnace **10***c* is provided with a forehearth or depending portion **155**. The construction **155** is formed with leg portions **158** and **159**. The portion **158** is formed with a downwardly extending passage **160** and the portion **159** is formed with a similarly shaped downwardly extending passage **162**.

The depending portions **158** and **159** support an annularly shaped portion **161**. The portion **161** is formed with an annular chamber **163** which is in communication with both passages or wells **161** and **162** and receive molten glass or other molten material from the furnace **10***c*. Disposed in the portion **161** is an annularly shaped feeder **164** formed with tips or projections **165** extending radially inwardly of the annular feeder **164**. The projections **165** are formed with orifices or outlets **167** through which the molten material in the annular chamber **163** is extruded under pressure to form streams or primaries **50***c* of the fiber-forming material.

The molten material in the passages or chambers **160** and **162** and the annular chamber **163** is under a pressure greater than the normal head of glass in the chambers **160** and **162**. The portion **155** of the forehearth is formed with a circular cylindrical chamber or bore **174**. Extending through an opening in the upper wall of the melting furnace **10***c* is a shaft **176** which is equipped with a collar **177** to position the rod or shaft **176**.

The shaft **176** extends into the chamber **174** and is equipped with a pair of propeller or screw-like members **180** and **182**. The blades of members **180** and **182** are of a spiral pitch such that rotation of members **180** and **182** in the proper direction impresses downwardly acting pressure upon the glass or other molten fiber forming material contained in the passages or chambers **160, 162** and **163**. The shaft **176** may be driven by any electric motor (not shown) or by other suitable means to rotate the members **180** and **182**.

Through this arrangement, a substantial pressure is exerted upon the glass or molten material contained in the annular feeder **164**, the pressure being effective to extrude the fine streams **50***c* in substantially horizontal directions into an attenuating blast as illustrated in Figure 10. The pressure may be controlled by regulating the speed of rotation of the members **180** and **182**.

Arranged in the space between the depending leg portions **158** and **159** of the material feeding means is a burner or blast producing means **186**. The burner **186** is inclusive of a metal shell **188** which is lined with a high temperature refractory **189** defining a combustion chamber or confined zone **190**. The rear of the burner is provided with a member **193** formed with a manifold chamber **195** into which a combustible mixture is delivered through a mixture supply pipe **197**. A rear wall **200** of the chamber **190** is formed with a large number of small channels or passages **202** through which the mixture is delivered into the chamber **190**, the wall **200** forming a fire screen to avoid preignition in the manifold **195**.

The depending end zone of the burner **186** is formed with a circular orifice **205** of restricted character in that its cross sectional area is one-quarter to one-eighth of the cross sectional area of the chamber **190**. The combustible mixture is delivered to the combustion chamber **190** under a comparably low pressure and is substantially completely burned within the chamber **190**. The burning gases undergo great expansion and are heated to a temperature of 3000° F. or more which is above the attenuating temperature of the glass.

The burned gases are projected from the chamber **190** through the restricted orifice **205** to form a substantially circular cylindrical blast B2 into which the streams or primaries **50***c* are projected, the blast moving downwardly in a direction substantially normal to the plane of the paths om movement of the streams **50***c* into the blast. The streams or primaries **50***c* are attenuated to fine fibers by the heat and velocity of the gases of the blast.

As shown in Figure 9, the attenuated fibers F are entrained in the downwardly projected blast and are collected upon the upper flight **70***c* of a foraminous conveyor in the manner described in connection with the form of the apparatus shown in Figure 1. A suction chamber **74***c* is disposed beneath the fiber collecting region to assist in collecting the fibers and to carry away spent gases of the blast.

It is to be understood that the pressurizing means **180** and **182** shown in Figure 9 may be used with the other forms of apparatus disclosed. The batch or glass feeding means and the pressurizing means shown in Figures 1 and 6 may be utilized in the construction shown in Figure 9 in lieu of or supplementing the mechanical pressurizing means shown in Figure 9.

Figure 12 illustrates another form of apparatus of the invention. In this form, the melting furnace **210** is provided with a horizontally extending forehearth construction **212**. Glass batch is introduced into the chamber **214** of the furnace through a tube or pipe **216** provided with a pair of spaced valves **218** operable to admit the material into the chamber without appreciable variation of pressure in the chamber. Burners **220** or other suitable heating means are utilized to reduce the batch material to a molten state.

Additional burners or heating means **222** may be disposed in the forehearth in order to maintain the glass at the desired viscosity therein. The furnace and forehearth are pressurized in any suitable manner. The burning gases from the burners **220** and **222** may be utilized for the purpose, or gases under pressure may be conveyed into the chamber **214** by means of a pipe **226**. Valve means **228** associated with the pipe **226**, which may be either manually operated or of an automatic pressure regulating type, may be used to control or regulate the pressure in the chamber **214**. A depending wall portion **230** disposed between the furnace chamber **214** and the forehearth forms a skimmer block, the molten material flowing through the passage **232** from melting chamber into the forehearth. One or more vent openings **234** may be formed in the wall **230** for equalizing the pressures in the chamber **214** and in the forehearth **212**.

A wall of the forehearth **212** is provided with a feeder or bushing **236** having nozzles or projections **238** through which streams or primaries **50***d* are projected into a blast B3. The blast is formed of combustible gases burned within a chamber or confined zone **57***d* of a burner **55***d*. The burner illustrated in Figure 12 is of the same construction as the burner **55** shown in Figure 1. The streams or primaries **50***d* are attenuated to fibers by the intensely hot, high velocity blast B3 in the same manner that the streams **50** are attenuated to fibers in the form of the apparatus shown in Figure 1.

In all forms of feeder construction illustrated, a current of electrical energy may be passed therethrough to heat the material in the feeder in order to accurately control the viscosity of the glass or other molten material at its zone of discharge. While several means of establishing pressure on the glass supply have been shown and described herein, it is to be understood that any suitable pressure establishing means may be used. The pressure impressed on the glass supply should be sufficient to project the streams or primaries in substantially horizontal directions so that the primaries are delivered into the blast in directions substantially normal to the path of travel of the gases of the blast.

It is apparent that, within the scope of the invention, modifications and different arrangements may be made other than is herein disclosed, and the present disclosure is illustrative merely, the invention comprehending all variations thereof.

I claim:

1. A method of producing fibers from heat-softenable, fiber-forming material including the steps of establishing a quantity of the fiber-forming material in a molten condition in a stationary chamber, impressing pressure effective on molten material in the chamber, projecting a plurality of streams of the molten material from the chamber by the pressure impressed on the molten material, establishing a high velocity gaseous blast wherein the gases of the blast move in directions normal to the projected streams and in engagement with the streams, the pressure on the molten material being of sufficient magnitude to project the streams by their energy of motion into the gaseous blast, and attenuating the material of the streams to fibers by the gaseous blast.

2. A method of producing fibers from heat-softenable, fiber-forming material including the steps of establishing a quantity of the fiber-forming material in a molten condition in a stationary chamber, impressing fluid pressure effective on the molten material in the chamber, projecting a plurality of streams of the molten material from the chamber in substantially horizontal directions by the pressure on the molten material in the chamber, establishing a high velocity gaseous blast wherein the gases of the blast move in directions normal to the paths of the projected streams and in engagement with the streams, the pressure effective on the streams of molten material being of sufficient magnitude to project the streams at substantial velocities by their energy of motion into the gases of the blast, and attenuating the material of the streams to fibers by the gaseous blast.

3. Apparatus of the character disclosed, in combination, a stationary receptacle adapted to contain a quantity of molten fiber-forming material, a stationary feeder associated with the receptacle provided with a plurality of orifices through which streams of the material are projected, means for establishing a high velocity gaseous

blast wherein the gases of the blast move in directions substantially normal to the paths of the projected streams, and pressurizing means associated with the molten material adapted to establish sufficient pressure effective on the material at the region of the orifices to project the streams at substantial velocities by their energy of motion through the blast-induced air stream into the blast whereby the streams are attenuated into fibers by the blast.

4. Apparatus of the character disclosed, in combination, a stationary receptacle adapted to contain a quantity of molten fiber-forming material, a stationary feeder associated with the receptacle provided with a plurality of orifices through which streams of the material are projected in substantially horizontal directions, means for establishing a high velocity gaseous blast wherein the gases of the blast move in directions substantially normal to the paths of the projected streams, and pressurizing means associated with the molten material arranged to establish sufficient pressure effective on the molten material at the region of the orifices to project the streams at substantial velocities by their energy of motion through the blast-induced air stream into the blast whereby the streams are attenuated into fibers by the blast.

5. A method of producing fibers from heat-softenable, fiber-forming mineral material including the steps of establishing a supply of molten mineral material in a relatively stationary confined zone, impressing fluid pressure in the confined zone above the supply of molten material, regulating the pressure in the confined zone, establishing a high velocity gaseous blast of a temperature above the attenuating temperature of the material, projecting streams of the molten material substantially horizonally from the pressurized supply under influence of the regulated pressure into the gases of the blast moving in a substantially vertical direction, the regulated pressure effective on the streams of molten mineral material being of sufficient magnitude to project the streams at substantial velocities by their energy of motion into the gases of the blast whereby the forces of the balst continuously attenuate the horizontally projected streams into fibers of varying lengths.

6. A method of producing fibers from heat-softenable mineral material including the steps of establishing a supply of molten mineral material, impressing fluid pressure on the molten mineral material, establishing a high velocity gaseous attenuating blast of generally rectangular cross section, projecting streams of the molten mineral material substantially horizontally from the pressurized supply into one side of the blast in directions substantially normal to the direction of movement of the gases of the blast, the pressure on the molten material being of sufficient magnitude to project the streams by their energy of motion into the gaseous blast whereby the streams are continuously attenuated to fibers by the blast.

7. A method of producing fibers from heat-softenable mineral material including the steps of establishing a supply of molten mineral material, impressng pressure on the molten mineral material, establishing a downwardly directed high velocity gaseous attenuating blast of generally rectangular cross section, projecting streams of the molten mineral material from the pressurized supply into both sides of the blast in directions generally normal to the direction of movement of the gases of the blast, the pressure on the molten mineral material being of sufficient magnitude to project the streams by their energy of motion into the gaseous blast whereby the streams are continuously attenuated to fibers.

8. A method of producing fibers from heat-softenable mineral material including the steps of establishing a supply of molten mineral material in a stationary chamber, impressing pressure on the molten mineral material in the chamber, establishing a downwardly-directed gaseous blast of high velocity, and projecting streams of the molten material radially into the blast in directions substantially normal to the path of the blast, the pressure on the molten mineral material being of sufficient magnitude to project the streams by their energy of motion into the gaseous blast whereby the blast continuously attenuates the projected streams to fibers.

9. A method of producing fibers from heat-softenable mineral material including the steps of establishing a supply of molten mineral material in a stationary chamber, impressing pressure on the molten mineral material in the chamber, establishing a substantially circular cylindrical gaseous blast of high velocity, and projecting streams of the molten material from the pressurized supply radially into the blast in directions substantially normal to the axis of the blast, the pressure on the molten mineral material being of sufficient magnitude to project the streams by their energy of motion into the gaseous blast whereby the blast continuously attenuates the projected streams to fibers.

10. A method of producing fibers from heat-softenable mineral material including establishing a supply of molten mineral material in a stationary chamber, impressing pressure on the supply, providing a generally annularly-shaped, high velocity gaseous blast of a temperature above the attenuating temperature of the material, projecting streams of the molten material from the pressurized supply in generally radial directions into the annularly-shaped blast, the pressure on the molten mineral material being of sufficient magnitude to project the streams by their energy of motion into the gaseous blast whereby the streams are continuously attenuated to fibers by the velocity of the gases of the blast.

11. Apparatus of the character disclosed, in combination, a stationary receptacle adapted to contain a supply of molten fiber-forming material, a stationary feeder arranged to receive molten mineral from the supply, pressurizing means for maintaining pressure on the material in the feeder, means for regulating the pressure in the feeder, said feeder being formed with a plurality of orifices in a side wall thereof through which streams of molten material are projected substantially horizontally of the feeder by the pressure on the material, means for establishing a high velocity blast, said pressurizing means being adapted to establish sufficient pressure effective on the material at the region of the orifices to project the streams at substantial velocities through the blast induced air stream into the blast, the attenuating blast engaging the streams in a direction substantially normal thereto to attenuate the streams to fibers of varying lengths, and means for restricting the flow of air induced by the velocity of the blast.

12. Apparatus of the character disclosed, in combination, a receptacle adapted to contain a supply of molten fiber-forming material, means for establishing a high velocity gaseous blast, a feeder disposed at each side of the blast adapted to receive molten material from the supply, means for impressing pressure on the material in the feeders, said feeders being formed with orifices through with streams of the material are projected into the blast from opposite sides thereof, said pressure impressing means being adapted to provide sufficient pressure on the material at the region of the orifices to project the streams at substantial velocities by their energy of motion through the blast induced air stream into the blast whereby the streams are attenuated to fibers by the velocity of the gases of the blast.

13. Apparatus of the character disclosed, in combination, a stationary tank adapted to contain a supply of molten fiber-forming material, a stationary feeder associated with the tank and adapted to receive molten material from the tank, pressurizing means for impressing pressure on the material in the feeder, said feeder being formed with a plurality of orifices in a side wall thereof through which streams of the molten material are projected in generally horizontal directions by the pressure

on the material, an internal combustion chamber in which a combustible mixture is adapted to be burned, a wall of the chamber having a restricted orifice through which the gases of combustion are discharged as a high velocity blast of a temperature above the attenuating temperature of the fiber-forming material, said pressurizing means being adapted to establish sufficient pressure effective on the material at the region of the orifices to project the streams at substantial velocities through the blast induced air stream into the blast, said blast engaging the streams in a direction normal to the paths of the streams for attenuating the same to fibers.

14. Apparatus of the character disclosed, in combination, a stationary tank adapted to contain a supply of molten fiber-forming material, means for impressing pressure on the material, a feeder associated with the tank and adapted to receive molten material from the tank, said feeder having a plurality of orifices arranged in an annular pattern through which streams of the material are projected in radial directions, means for burning a combustible mixture in a chamber, said chamber having a wall formed therein through which the burned gases are discharged as a high velocity blast of a temperature above the attenuating temperature of the material into engagement with the radially moving streams, said pressure impressing means being adapted to establish sufficient pressure effective on the material at the region of the orifices to project the streams at substantial velocities through the blast induced air stream into the blast whereby the streams are attenuated into fibers by the blast.

15. Apparatus of the character disclosed, in combination, a stationary tank adapted to contain a supply of molten fiber-forming material, a plurality of feeders associated with the tank and adapted to receve molten material from the tank, means for impressing pressure on the material in the feeders, each of said feeders being formed with a plurality of orifices through which streams of the molten material are projected in substantially horizontal directions by the pressure on the material, an internal combustion chamber in which a combustible mixture is adapted to be burned, a wall of the chamber having a restricted orifice through which the gases of combustion are discharged as a high velocity blast of a temperature above the attenuating temperature of the fiber forming material, said pressure impressing means being adapted to establish sufficient pressure effective on the material at the region of the orifices to project the streams at substantial velocities through the blast induced air stream into the blast, said blast engaging the streams projected from the feeders to attenuate the streams to fibers.

16. Apparatus of the character disclosed, in combination, a stationary tank adapted to contain a supply of molten fiber-forming material, means for impressing pressure on the supply in the tank, a feeder associated with the tank and adapted to receive molten material from the tank, said feeder having a plurality of orifices arranged to an annular pattern through which streams of the material are projected in radial directions under the pressure in the tank, means for establishing an annularly shaped high velocity gaseous blast of a temperature above the attenuating temperature of the material, said pressure impressing means being adapted to establish sufficient pressure effective on the material at the region of the orifices to project the streams at substantial velocities through the blast induced air stream into the annularly shaped blast, said annularly shaped blast engaging the radially moving streams to attenuate the streams to fibers.

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