Sept. 13, 1955 E. FLETCHER 2,717,416

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 7, 1951 3 Sheets-Sheet 1

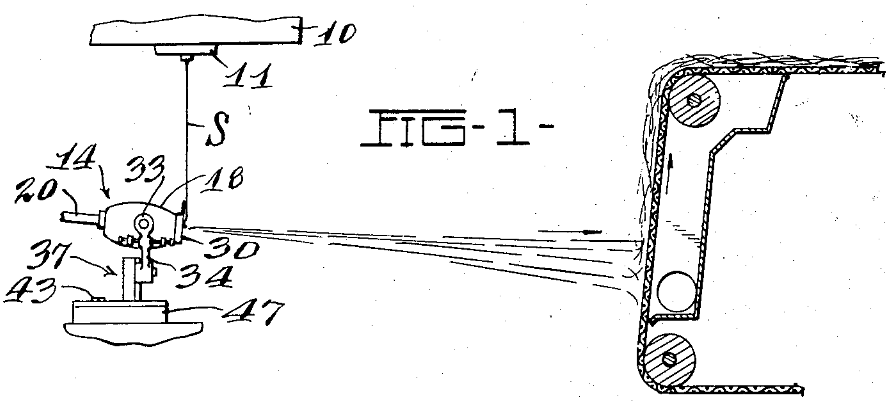

FIG-1-

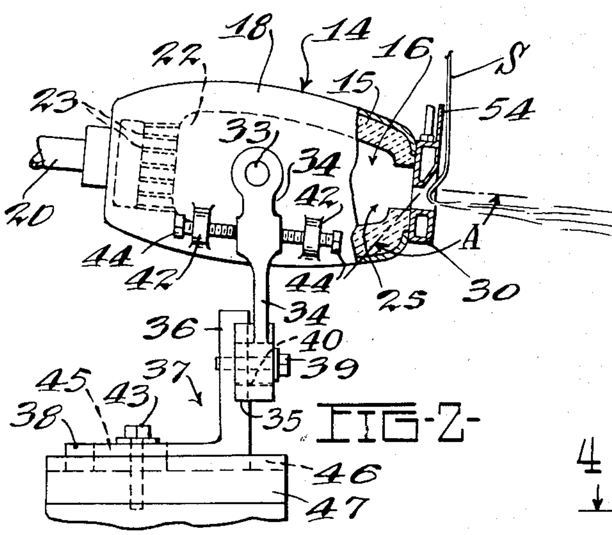

FIG-2-

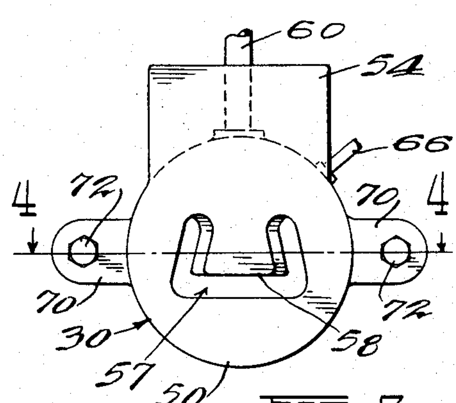

FIG-3-

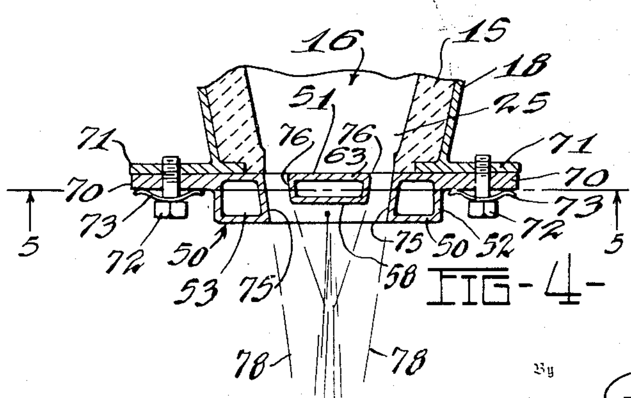

FIG-4-

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METHOD AND APPARATUS FOR PRODUCING FIBERS

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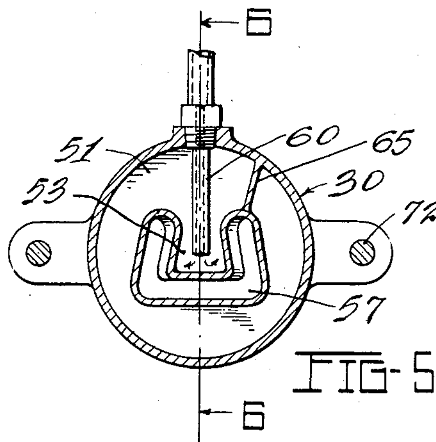

FIG-5-

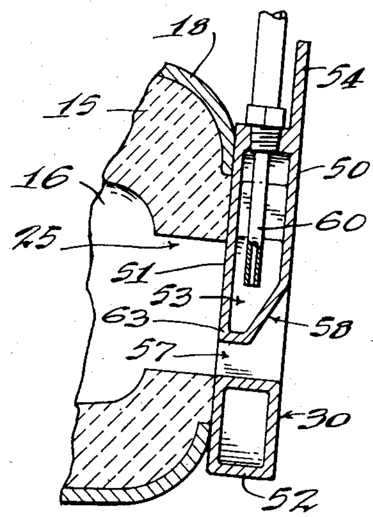

FIG-6-

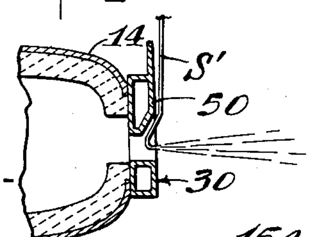

FIG-8-

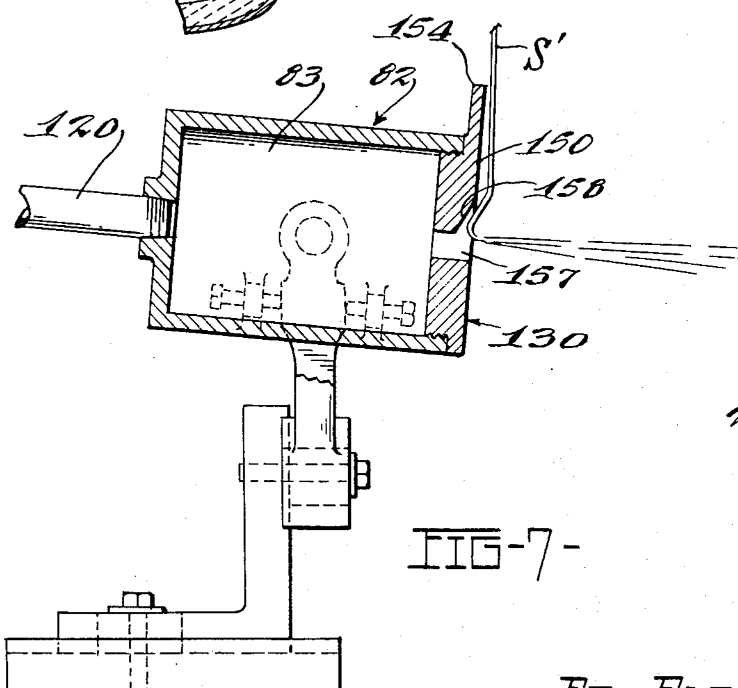

FIG-7-

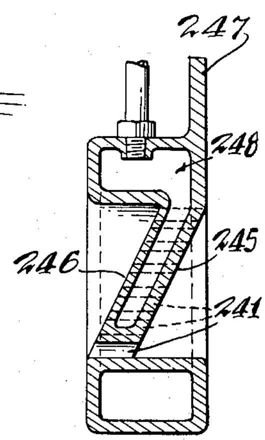

FIG-17-

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METHOD AND APPARATUS FOR PRODUCING FIBERS

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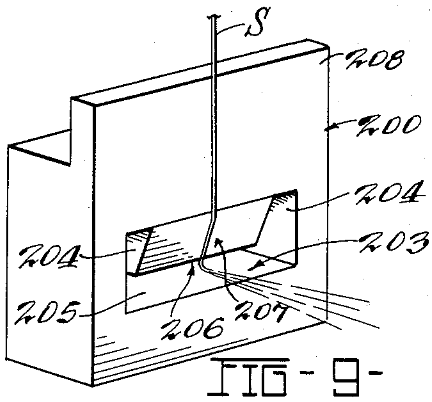

FIG-9-

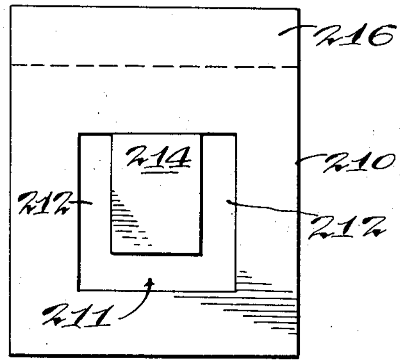

FIG-10-

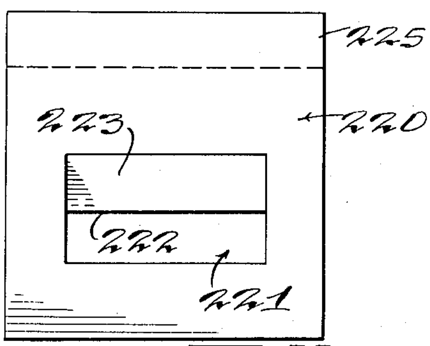

FIG-11-

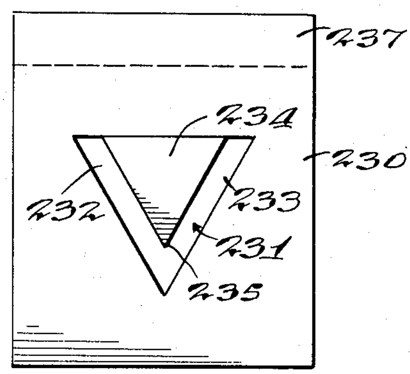

FIG-12-

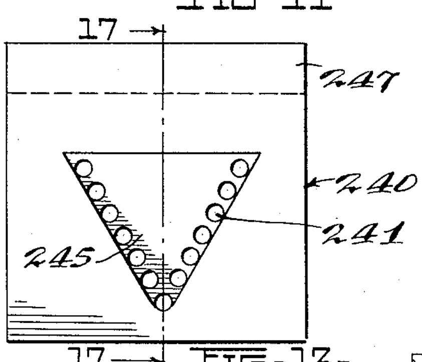

FIG-13-

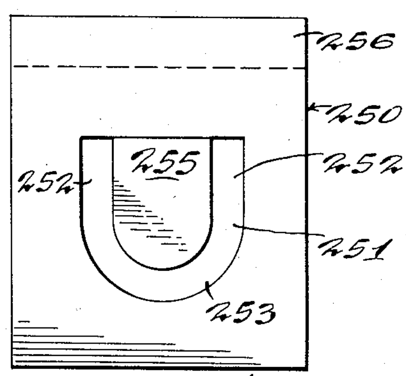

FIG-14-

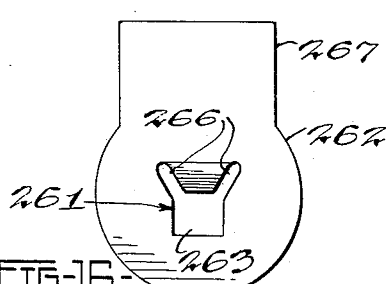

FIG-16-

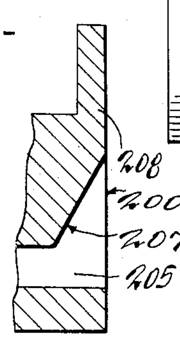

FIG-15-

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United States Patent Office

2,717,416

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2,717,416

METHOD AND APPARATUS FOR PRODUCING FIBERS

Ed Fletcher, Newark, Ohio, assignor to Owens-Corning Fiberglas Corporation, a corporation of Delaware

Application March 7, 1951, Serial No. 214,250

26 Claims. (Cl. 18—2.5)

This invention relates to an improved method and apparatus for producing fibers from thermoplastic or thermofusible fiber-forming materials particularly mineral materials as, for example, glass, rock or slag, and is a continuation-in-part of my application Serial No. 197,946, filed November 28, 1950.

Mineral fibers have been produced commercially by flowing streams of molten mineral such as glass and subjecting the streams to blasts of steam or air projected in the general direction of movement of the streams for attenuating the same to fibers.

It has also been a practice to attenuate or form fibers from glass filaments or rods in which the solid filament or rod is fed into a high velocity blast of burned gases wherein the extremity thereof becomes molten and is drawn or attenuated by the force of the blast to produce very fine glass fibers of varying lengths in the nature of from one to two and one-half microns in diameter. The hot blast is established by burning a combustible mixture of fuel and air in a confined chamber and directing the hot gases of combustion at high velocities through a restricted orifice or discharge outlet in a wall of the combustion chamber into contact with the glass rod or filament to form fibers in the manner disclosed and described in U. S. Patent No. 2,489,243 issued November 22, 1949, to C. J. Stalego.

In order to secure reliable operation of this method and apparatus for commercial adaptation, a glass rod or filament in substantially solidified form is employed. Such process is continuous in its operation, the flowing streams of glass from a supply being drawn to a filament or rod form are rapidly chilled and solidified as they move away from the supply. The rods or filaments are moved or conveyed into the zone of hot burned gases emanating from the discharge outlet or orifice of the combustion chamber and attenuated to fiber form by the high velocity blast.

The utilization of the above method results in considerable waste of heat as the glass stream is permitted to reach a solidification state and is then reheated in the high velocity hot blast to soften the same to an attenuating temperature. Various attempts have been made to flow a stream of molten or thermoplastic material such as molten glass into a very hot, high velocity blast of burned gases emanating from a burner of the character herein mentioned in an endeavor to produce fine fibers directly from the molten stream by attenuation or fiberization. Most endeavors in this direction have not been successful and especially from the standpoint of commercial operation for various reasons.

Apparently due to the high velocity of the blast, a very high speed flow of induced air is set up which forms a moving envelope about the blast. In order to flow a stream of molten material into this envelope to attenuate the stream by the blast requires that the stream penetrate the envelope or moving layer of induced air. Instead of the stream penetrating the envelope, the tendency is for the stream to be deflected by the moving envelope and

2

ride thereon without encountering the hot gases of the blast with the result that little or no attenuation or fiberization takes place because the glass stream is carried beyond the zone of maximum heat in the blast. The limited attenuation which does occur takes place at a considerable distance from the outlet of the burner. Hence such method is inefficient and incapable of control of the attenuation operation. If the glass is in a more viscous condition, it may succeed in breaking through the induced air layer but the portion breaking through the air layer into the blast results in little attenuation as the stream breaks up into small pellets in lieu of attenuation to fiber form.

The flow of air induced by the attenuating blast also affects the stream of molten material by causing it to move laterally along with the flow of induced air so that it is impossible to direct the stream into the blast near its origin. Instead the molten stream moves downstream of the blast and if it enters the blast at all, it occurs at a zone somewhat removed from the origin. The highest gas velocities and temperatures exist in the blast at or near its origin, and entrance of the stream of fiber-forming material in a zone of the blast spaced any appreciable distance from the origin thereof contributes to a lower efficiency and impairment of the quality of fibers produced.

In the conversion of molten mineral material, such as rock, glass, or slag, into fibrous form by engaging a flowing stream of the molten material with a blast of steam or air, many of the same problems met with in the use of a high temperature high velocity gaseous blast are also present. Entry of the stream of molten material into the blast must be effected properly if a complete or substantially complete fiberization of the molten material is to be obtained.

In the present invention the stream of molten material is introduced into the very core of the blast where the velocity of the blast is capable of converting the material to fiber form with the highest degree of efficiency. At the same time the molten material is introduced into the blast in such a way that there is an anchor or resistance to movement created so that the material subjected to the force of the blast is pulled or drawn out against a relatively stationary part of the stream so that an actual stretching out of the molten stream occurs much in the same way that a strip of rubber is stretched out if one end is held while the other is moved away from the stationary end.

The method of the present invention embraces the utilization of an induced air layer set up by a moving blast of gases in a manner which facilitates movement of a molten stream of fiber-forming material into the blast of gases whereby efficient attenuation or fiberization of the material is attained in which the critical factors and characteristics of the method may be readily controlled and maintained whereby the method may be used for the efficient, economical and continuous production of fine fibers on a commercial scale at optimum conditions of operation.

An object of the invention resides in the provision of a method wherein an induced air layer is caused to assist in moving or conveying the molten stream of fiber-forming material in an angular direction toward the blast so as to effect attenuation or fiberization of the glass at the most efficient zone of the blast.

Another object of the invention resides in a method of feeding a stream of molten fiber-forming material in juxtaposition with a surface in a manner whereby the stream is separated from the surface by a thin layer of induced air whereby the stream is conveyed to the most efficient fiber attenuating or fiberization zone of the blast.

Another phase of the method embraces the utilization of an induced air layer motivated by a moving blast of intensely hot burned gases in a manner facilitating movement of a molten stream of fiber-forming material into the zone of intense heat of the blast whereby efficient attenuation or fiberization of the material is attained in which various critical factors involved in carrying out the method may be controlled and maintained to attain economical and continuous production of fibers on a commercial scale.

Another object of the invention resides in the provision of an apparatus for carrying out the method of the invention wherein a molten stream of material such as a heat softenable mineral is caused to move in substantial parallelism with but out of engagement with a canted surface which is maintained at a relatively low temperature compared to that of a hot gaseous blast so that the molten stream does not adhere or stick to the canted surface impairing the efficiency of the hot blast for fiberization purposes. The molten stream is caused to traverse a path adjacent the surface by reason of differential pressures set up by interrupting the normal path of an induced air stream set up by a moving blast of gases.

Another object of the invention is the provision of an apparatus formed with a surface along which a stream of molten fiber-forming material is adapted to flow, the surface being configurated to influence the path of travel of the molten stream whereby the extremity of the stream in reaching the blast of gases is turned or bent through an obtuse angle and attenuated by the blast, the pressure directing the molten stream in parallelism with the canted surface providing a resistance operative against the stream adjacent its turning point in the blast presenting an inertia factor tending to resist change in direction of movement of the stream prior to its entrance into the attenuating zone.

Another object of the invention resides in an apparatus involving a means for modifying the normal path of travel of an air layer induced by movement of a blast of gases and of configurating the discharge opening in the burner in a manner to cause the blast of gases to fold inwardly upon the fiber attenuating zone of the blast whereby the fibers are formed by attenuation or fiberization in the core or body of the blast. This arrangement provides for an efficient and continuous fiberization or fiber attenuating method in which fibers of a substantially uniform diameter may be continuously produced without the formation of slugs or pellets or other nonusable configurations.

Another object resides in the control and orientation of pressures effective to establish a locus of travel of the molten stream so that the stream remains positioned to permit drawing of fibers from the end thereof as the latter is projected into a high velocity blast of gases.

Another object of the invention is the provision of apparatus including a means of producing a high velocity blast of gases which may be adjustably disposed with respect to a moving stream of fiber-forming material whereby the most efficient attenuation or fiberization of the material may be attained.

Still a further object of the invention is the provision of means associated with an internal combustion burner for adequately cooling a surface adjacent the molten stream of mineral material in a manner obviating tendency of the molten glass to adhere to the surface.

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 semidiagrammatic view of an apparatus for carrying out the method and principles of the present invention;

Figure 2 is an elevational view partly in section showing an internal combustion burner and a form of supporting means therefor;

Figure 3 is an enlarged end view of a portion of the apparatus illustrated in Figure 2 showing the contour of the orifice through which the attenuating blast is projected;

Figure 4 is a horizontal sectional view taken substantially on the line 4—4 of Figure 3;

Figure 5 is a vertical sectional view taken substantially on the line 5—5 of Figure 4;

Figure 6 is a vertical longitudinal sectional view through the apparatus, the section being taken substantially on the line 6—6 of Figure 5;

Figure 7 is a vertical longitudinal sectional view of a modified form of apparatus showing the principles of the invention embodied in a device for attenuating streams of molten mineral material by means of a blast of steam or air;

Figure 8 is a sectional view of a portion of the apparatus of Figure 1 showing a modified position of the orifice plate and burner relative to the stream of material;

Figure 9 is an isometric view of a member illustrating a plate or member having an orifice of modified contour for an attenuating blast;

Figure 10 shows another shape of blast orifice;

Figure 11 illustrates another form of blast orifice of horizontally elongated character;

Figure 12 illustrates another form of blast orifice of substantially V-shaped configuration;

Figure 13 illustrates another form of apparatus producing an attenuating blast emanating from a plurality of closely spaced orifices oriented to produce a blast of particular contour;

Figure 14 illustrates an apparatus for producing an attenuating blast of U-shaped contour;

Figure 15 is a fragmentary sectional view illustrating the slanted or inclined surface of the tongue or portion of the plate bounding the orifice forming the contour of the blast in the several forms of the invention;

Figure 16 shows another form of blast orifice, and

Figure 17 is a sectional view taken substantially on the line 17—17 of Figure 13.

While the method and apparatus of the present invention are particularly adaptable for processing molten mineral materials such as rock, slag, glass and the like into fine fibers, it is to be understood that the invention may be utilized for processing other thermo-softenable materials into fiber form.

As shown in semidiagrammatic form in Figure 1, there is illustrated a receptacle **10** adapted to contain a supply of molten material such as glass, the glass contained in the receptacle **10** being maintained in the molten condition by electrically energized heating means (not shown) or other suitable heating medium. Disposed beneath the receptacle **10** is a bushing **11** provided with an opening through which flows a stream of molten material S from the supply in the receptacle. The stream is directed into a gaseous blast emanating from an orifice, the stream being directed in a particular manner whereby fine fibers are formed from the stream by fiberization or attenuation.

A suitable burner of the internal combustion type may be utilized for producing a high velocity blast in carrying out the method of the present invention. The burner **14** is inclusive of a hollow body **15** of refractory material forming a combustion chamber **16**. The burner may be surrounded by or encased in a metal shell **18** and connected to the rear end of the burner is a pipe **20** for conveying or feeding a combustible gaseous mixture into the combustion chamber **16**. Positioned adjacent but spaced from the rear end of the burner is a wall **22** provided with a plurality of perforations or minute passages **23** extending therethrough providing a screen to confine combustion in the chamber **16**.

The combustible mixture in the chamber **16** is continuously burned therein to provide an extremely hot, high velocity gaseous blast which is projected through or emanates from the orifice 25 of the burner. Secured to the forward or open end of the burner is a member or fitting 30 which is configurated in a manner to facilitate attenuating or fiberizing a molten stream of fiber-forming material to form fine fibers in a manner hereinafter explained.

The proper relationship between the burner position and the stream of molten material must be secured and maintained in order to attain most efficient operation. It is therefore desirable that the burner be supported in a manner facilitating adjustment relative to the molten stream so that the most efficient position for attenuation may be attained. Moreover variations in the composition of the molten material may require adjustment of the position of the burner to secure satisfactory results. To this end the burner shell 18 may be formed with laterally and horizontally extending trunnions 33 journalled in a bracket 34 which may be supported upon an upwardly extending leg 36 of an L-shaped member 37. The member 34 may be provided with a portion 35 having a vertical groove formed therein to receive the portion 36 of the member 37. The member 37 is provided with a threaded opening to receive a securing bolt 39 passing through a vertically disposed slot 40 formed in member 35, this construction forming a means of securing vertical adjustment of the burner.

The shell 18 of the burner may be provided with outwardly projecting lugs 42 provided with threaded openings to receive adjusting screws 44, the inner ends of the screws adapted to engage opposed surfaces on the member 34. By manipulating the screws 44 the burner may be adjusted about the axes of the trunnions 33 so as to shift or vary the angular position of the burner with respect to the path of travel of the molten stream S.

The horizontal leg 38 of the L-shaped member 37 may be disposed in a groove 46 formed in a stationary support 47 and disposed longitudinally of the burner. A securing bolt 43 passing through an elongated slot 45 formed in the member 38 is adapted to secure the member 37, bracket 34 and burner 14 in a position of longitudinal adjustment.

Through the provision of adjustable supporting means of the character above described or similar means, the burner 14 may be tilted angularly with respect to the molten stream, adjusted in a vertical direction substantially parallel therewith or moved toward or away from the stream. By this or similar means the most efficient position of the burner for attenuation or fiberization purposes may be had. Furthermore such adjustments provide for utilization of the burner with various compositions of fiber-forming material whose viscosity characteristics may vary and the burner position therefore modified or shifted to obtain the most efficient position of operation. Figures 1 and 2 illustrate an adjusted position of the burner 18 and the orifice plate or member 30 wherein the obverse face 50 is disposed at a slight angle with respect to the flowing glass stream S in a direction of convergence with the source of the stream. This may be a position facilitating most efficient operation with a stream of fiber-forming material of a particular character and wherein the stream may be of a predetermined size and relative viscosity. Figure 8 illustrates another position of adjustment of the burner 14 and the plate 30 wherein the surface or face 50 is positioned at a different angle with respect to the flowing glass stream S in a general direction of divergence relative to the source of the stream, a position of adjustment which has been found to provide efficient functioning of the apparatus under certain operating conditions.

The method of the present invention is carried on in conjunction with a burner of the hereinbefore described character with the outlet or orifice configurated to attain a particular form of hot, high velocity blast suitable for attenuating a molten stream directly into fine fibers. In the embodiment illustrated, the fitting 30 applied or affixed to the burner is shaped in a manner to perform several functions for facilitating formation of fibers from the molten stream. As will be seen from Figures 3 through 6 inclusive, the member or fitting 30 is of generally circular formation having front and rear walls designated respectively 50 and 51 which are welded, cast or otherwise secured to a circular wall 52 forming an enclosed chamber 53. The front wall 50 is projected upwardly in a substantially rectangular shape indicated at 54 and serves to obstruct, interrupt and modify the direction of flow of a moving layer of air induced by the blast which would otherwise be drawn into the blast at a zone causing interference with satisfactory fiber formation.

The orifice or nozzle formed in the member 30 for the passage of the hot blast of burned gases is generally of a U-shaped formation as viewed in elevation illustrated in Figures 3 and 5 and designated 57. As shown in Figures 3 and 5 the front wall 50 has an angularly arranged tongue-like portion 58 which slants or is canted toward the combustion chamber of the burner in the manner illustrated in Figure 6, the function of this surface being hereinafter explained.

As the blast of hot gases is of a temperature which would otherwise fuse the metal of the fitting or member 30, means is provided for cooling or maintaining the surface portions of the fitting which are subjected to the intense heat of the blast at a temperature below that at which the molten material would adhere or cling to the surface. As particularly shown in Figures 5 and 6, a tube 60 extends downwardly through the circular wall 52 into the chamber 53 formed by walls 50, 51 and 52 and has its outlet adjacent the canted wall 58. The tube 60 is adapted to convey cooling fluid or liquid such as water into the chamber. The outlet end of the tube is preferably disposed adjacent the central depending portion 63 in order that this portion of the fitting be adequately cooled as it is in the position of most intense heat of the blast. A baffle wall 65 is disposed in the position illustrated in Figure 4 and an outlet pipe 66 is formed in the circular wall 52 to facilitate continuity of flow of cooling medium throughout the chamber 53.

As illustrated in Figure 5 the cooling medium is conveyed into the chamber of the fitting through the tube 60 which discharges the cooling fluid adjacent the portion 63 and the wall 58, the cooling fluid flowing in a generally circular direction around the wall 52 and through the outlet tube 66.

The member or fitting 30 may be secured to the burner construction 14 by a suitable means as for example integral ears 70 formed on the fitting arranged to mate with projecting portions 71 formed on the metal shell of the burner, securing bolts 72 being employed to support the fitting 30 adjacent the burner. By reason of the intense heat to which the burner and fitting are subjected, it is desirable to utilize a resilient means such as spring washers 73 in cooperation with bolts 72 to compensate for contraction or expansion resulting from variations in temperature.

With particular reference to Figure 4 it should be noted that the upwardly extending walls 75 and 76 of the orifice or nozzle 57 in the member 30 are arranged in converging directions so that the blast of hot gases passing through the upwardly extending portions of the orifice are directed into a converging relation as indicated in dotted lines at 78 so that the blast of gases at the time of their passage through the orifice 57 is generally U-shaped in cross-section, but by reason of the convergence of the walls 75 and 76 the gases in the upper leg portions of the blast are bent or turned inwardly and folded over as indicated at 78 at a zone of confluence to envelope the fiber-forming material during attenuation or fiberization substantially in the core or central zone of the blast. This folding-in action of the upper portions of the blast tends to negate the cooling effects of induced air currents which would otherwise impair the efficiency of the fiber-forming characteristics of the blast.

The operation of the apparatus hereinbefore described in carrying out the method of the invention is as follows: The stream of flowable fiber-forming material indicated at S flows from the bushing **11** in a substantially vertical downward direction until it attains a position adjacent the baffle **54**. The chamber **16** of the burner of the internal combustion type is supplied through the tube **20** with a combustible mixture of fuel and air which is ignited in the chamber **16** and burns in the confined zone of the chamber after the mixture passes through the openings **23** in the screen **22**. Substantially complete combustion takes place within the chamber **16** developing a high velocity blast of intensely hot burned gases which pass through the outlet **25** of the burner and through the U-shaped orifice or discharge nozzle **57** in the member **30**. The blast of gases moves away from the burner orifice at a high velocity which sets up or induces the adjacent air layer to move along the surface areas of the blast. The baffle **54** projects substantially upwardly along the stream S and modifies or obstructs the normal flow of induced air which would otherwise move along the upper surface zone of the blast. Through the modification of the path of travel of the induced air layer by reason of the presence of the baffle **54**, the air stream passing over and around the baffle **54** establishes or creates a zone of reduced pressure at the righthand side of the baffle as viewed in Figures 2 and 6 which acts upon the stream of fiber-forming material to cause the latter to continue its downward flow adjacent the front face of the baffle **54** but slightly spaced therefrom by reason of a thin layer of air enveloping the molten stream induced by its downward movement. The zone of reduced pressure set up by modifying the air flow induced by the blast is existent in the area of the canted surface **58**, a condition or force which is effective on the molten stream of material causing it to flow in substantial parallelism with the canted surface **58** into the blast discharge orifice **57**. As the surfaces of the baffle **54** and the canted portion **58** are relatively cool, being subjected to the cooling stream of water or other fluid moving through the chamber **53** of the fitting **30**, they present surfaces of reduced temperature sufficiently low so that the stream of glass or other molten material will not stick or adhere to the relatively cool surfaces. Moreover the molten stream as it flows progressively farther from the supply loses some of its heat while traveling or moving along the surface of the baffle **54** and the canted surface **58** aided by the temperature differential of the surfaces whereby its viscosity is slightly increased as it approaches the lower extremity of the canted surface **58** and flows into the blast of extremely hot gases emanating from the burner. As illustrated in Figures 1 and 2, the molten stream entering the blast is abruptly bent or turned through an obtuse angle indicated at A relative to its locus of flow along the surface **58** and is acted upon by the blast and fiberized or attenuated into fine fibers entrained in and moved axially of the blast by the velocity thereof.

The converging walls **75** and **76** of the upper portion of the orifice or nozzle **57** in member **30** augmented by the zone of reduced pressure adjacent the angularly disposed surface **58** direct or influence the upper portions of the gaseous blast to progressively fold in or converge to a zone of confluence as indicated at **78** in Figure 4 providing a solid blast enveloping the fibers during attenuation and avoiding contact of induced air currents with the fibers which would otherwise impair the efficiency of attenuation and quality and fineness of the fibers.

An important factor of the invention facilitating the successful attenuation or fiberization of the molten stream to fibers is the establishment of a pressure differential adjacent the canted surface **58** causing angular flow of the stream toward the origin of the blast so that the molten body tends to remain adjacent the canted surface from which the advancing extremity of the stream being rendered highly fluid by the intense heat of the blast is attenuated, drawn or formed into a multiplicity of fine fibers by the force of the blast. Thus the method and apparatus of the present invention provide for the flowing of a body of molten material into a zone under conditions from which it is possible to pull the material into fiber form without disrupting the continuity of flow of the molten stream to the attenuating or fiberizing zone. The method has been illustrated utilizing a single stream of material, but it may be employed to concomitantly attenuate several molten streams if desired.

Successful operation of the method of the present invention in order to attain complete fiberization of the glass stream resides in establishment of conditions whereby only the molten tip or extremity is acted upon by the blast. A resistance must be provided to prevent projection of the glass stream in its entirety into the blast or as blobs of unfiberized glass along the blast. A force couple, in effect, must exist so that the stream is caused to remain positioned to permit drawing or forming of fibers only from the end of the glass stream. In prior methods, this condition or resistance has been established through the use of solid filaments or primaries of glass fed at predetermined rates of speed into the interior of the blast, the solidity of the filaments of glass permitting them to be projected through the current of induced air and into the zone of intense heat of the blast.

Referring to Figure 7 (wherein similar parts are indicated by similar reference numerals raised to the series **100**) a steam or air blower patterned after the kind conventionally employed in the in the fiberization of certain types of mineral material such as slag or rock and its conversion into rock or slag wool is shown at **82**. This blower comprises a chamber **83**, preferably cylindrical in form. One end of the chamber **83** is connected with a pipe **120** by which steam or air under pressure is fed to the blower. In this form of invention, the other end of the chamber **83** is closed by a plate **130** having an orifice **157** therein substantially the same as the orifice **57** shown in the form of the invention in Figures 1 through 6. In this form of apparatus, however, the plate **130** may be solid since there is ordinarily no need for water cooling as in the previously described form of the invention.

The front face of the blower may be arranged in substantially the same relation to a stream of molten material as shown in Figures 1 and 2 of the drawings so that as the stream S′ of molten rock, slag, or glass flows downwardly from the opening in a conventional melting receptacle and by reason of the interruption or modification of the flow of the induced air layer by the abutment or projection **154** on the plate **130**, it is caused to follow along the front face **150** of the blower and then along the inclined surface **158** and is directed into the core of the blast as it leaves the lower end of the surface **158** in substantially the same manner as in the form of the invention shown in Figures 1 through 6. The blower may be adjusted whereby the front face thereof may be disposed in other relative positions with respect to the flowing stream S of fiber-forming material. For example, the blower may be positioned whereby the front face is tilted at a slight angle relative to the path of the stream of material in a direction divergent with respect to the source of the stream in a manner similar to that exemplified in Figure 8.

The blast of steam or air discharged from the blower and passing through the slot or nozzle **157** immediately takes hold of the extremity of the stream of molten material and draws it out against the resistance to such movement which is caused by the molten stream substantially reversing direction as it leaves the lower end of the inclined surface **158** and is carried along with the blast and concomitantly attenuated to fibers or fiberized by the velocity of the blast. As shown in Figure 7 the blower **82** is preferably adjustably supported in a manner similar to that illustrated in Figure 2.

In the forms of the present invention, the necessary resistance against which the blast operates to draw or spin fine fibers from the extremity of the molten stream is established by the force or acceleration acting rearwardly of the glass stream by the induced air sweeping toward and over the canted surface **58** of the tongue provided at the burner orifice. The pulling or attenuating forces of the blast are thus rendered effective at the knee of the glass stream where it is turned sharply into parallelism with the blast and are not effective along the incoming body of the glass stream which, being fluid, in itself has little or no resistance. The knee in the glass stream provided by the rearwardly directed induced air currents constitutes, in effect, a snubbing point from which fibers may be drawn by the high velocities of the gases in the blast.

It is to be understood that the high velocity blast and the molten stream of fiber-forming material should be brought into proper correlation in order to secure optimum conditions for the most successful and efficient attenuation of fiber formation. The burner **14**, and blower **82** if employed, are therefore rendered adjustable for pivotal movement and for movement horizontally and vertically in the manner herein described in connection with the form of the invention shown in Figures 1 through 6. These adjustments may be critical depending upon the type or character of composition of the molten material, the size of the stream or streams, the relative viscosity or degree of fluidity of the stream and the character of the attenuating blast employed.

The method and apparatus while especially usable for forming fibers from fusible mineral materials such as glass, slag and argillaceous rock may be advantageously employed for producing fibers from heat softenable resins or the like.

Figures 9 through 16 illustrate other forms of orifice plate or member adaptable for use with the burner **14** of the internal combustion type for generating an intensely hot, high velocity blast for attenuating the stream or streams to fibers, or for use with a steam or air blower of the character illustrated in Figure 7 for forming fibers.

Figure 9 illustrates a modified form of orifice plate or member **200** similar in character to the member **30** illustrated in Figures 3 and 6. The member **200**, adapted to be secured to the exit end of a burner for producing an intensely hot, high velocity blast or utilized with a jet of steam or air, is formed with an orifice **203** of generally U-shaped configuration including opposed vertically extending openings **204** connected by a horizontal opening **205**. Thus the blast of gases projected through the orifice **203** will be substantially of the configuration or shape of the orifice formed in member **200**. The formation of the vertical openings **204** in spaced relation provides a depending tongue **206** configurated with its front or obverse face **207** angularly disposed or slanted downwardly and rearwardly in the manner illustrated in Figure 15. The fitting **200** is formed with an upwardly extending projection, wall or abutment **208**, the front face of which forms a uniplanar continuation of the front face of the fitting **200**.

The principle of operation of this form of the invention is similar to that illustrated in Figures 1 through 6 inclusive. One or more streams "S" of molten glass or other material may be arranged to flow along the front face of the fitting **200** and, due to the modification or interruption of the normal path of the induced air stream by the projection or wall **208**, a zone of reduced pressure is established effective adjacent the angularly disposed surface **207** causing the stream of glass to be bent into substantial parallelism with but slightly spaced from the surface **207**. The extremity of the stream, entering the major portion of the blast emanating from the horizontal portion **205** of the orifice at which zone the tip of the molten stream is bent through an obtuse angle, is acted upon by the blast of gases and attenuated into fibers which are carried away by the blast to a fiber collecting zone. The laterally spaced vertical zones of the blast emanating from the openings **204** tend to envelop the tip portion of the molten stream undergoing attenuation and thus minimize or substantially eliminate a tendency for the stream to ride upon the surface of the gaseous blast, a condition which may impair efficient and satisfactory attenuation.

Figure 10 illustrates a modified form of U-shaped orifice wherein a member **210** is formed with an orifice **211** having spaced vertical openings **212** to impart a U-shaped configuration to the blast. The outer walls of the vertical openings **212** in the form of the orifice shown in Figure 10 are substantially equal to the horizontal length of the lower wall of the horizontal or connecting opening. The depending tongue portion **214** disposed between and forming the inner walls of the vertical opening **212** has its obverse face slanted downwardly and rearwardly in the manner illustrated in Figure 15. The orifice plate **210** is provided with an extension **216** similar to the extension or abutment **208** in the form of plate illustrated in Figure 9 for the purpose of impeding, diverting or changing the path of the air stream induced by a gaseous blast projected through the orifice **211**. Such obstruction acting on the air stream establishes a zone of reduced pressure adjacent the slanted obverse face of the depending tongue **214** so as to cause the molten stream of glass or other fiber-forming material to follow generally the contour or slant of the obverse face of the depending tongue **214**.

Figure 11 illustrates another form of orifice plate or member **220** provided with a rectangular orifice **221** in which the longer dimension extends horizontally. Adjacent the upper wall **222** of the orifice is a rectangular portion **223** which is slanted or inclined downwardly and rearwardly relative to the obverse face of the plate **220**. The character of the angularity or slant of the face is similar to that shown in Figure 15. The plate **220** is formed with an abutment or extended portion **225** as in the other forms of orifice plate for interrupting or modifying the normal flow of the induced air stream caused by the high velocity blast projected through the orifice **221** so as to set up a zone of reduced pressure adjacent the slanted surface **223** for the purpose of influencing the path of the stream of fiber-forming material along the contour of the slanting surface to facilitate attenuation of fibers from the advancing end of the molten stream entering the gaseous blast.

Figure 12 illustrates an orifice plate **230** formed with a V-shaped orifice **231** of converging elongated openings **232** and **233** between which depends a triangularly-shaped tongue **234**. The tongue **234**, as in the other forms of orifice plate, is slanted downwardly and rearwardly with the apex **235** spaced substantially rearwardly of the plane of the obverse face of the plate **230**. The plate **230** as in the other forms of construction is provided with an extension or wall portion **237** for modifying or diverting the path of the induced air stream to create a reduced pressure adjacent the slanted tongue **234**. The form of the invention illustrated in Figure 12 functions in substantially the same manner as the other forms hereinbefore described.

Figure 13 illustrates an orifice plate **240** having a plurality of closely spaced relatively small circular openings **241** arranged in two converging rows as illustrated. The gases are projected through the plurality of openings **241** to provide a generally V-shaped blast. The triangular portion **245** encompassed or bounded by the two rows of openings **241** is slanted rearwardly in the same manner as the tongue **234** in the form of the invention illustrated in Figure 12. As shown in section in Figure 17, the slanted section **245** is preferably fashioned with the rear wall **246** in substantial parallelism with the front surface to provide a section of uniform thickness at the zone of the openings **241**. Through this construction, the openings **241** are of substantially equal length so that the several portions of the blast established by the openings are projected at substantially equal velocities. The plate or member **240** may be formed with a hollow interior forming a chamber **248** to accommodate the circulation of cooling fluid such as air, water or other medium when the plate is used with an internal combustion burner. The cooling chamber may be dispensed with when the orifice plate is used with a steam or air blast. The plate **240**, as in the other forms of construction, is provided with an extension or projection **247** for interrupting or modifying the path of the induced air stream to establish or set up a zone of reduced pressure adjacent the slanted surface of the section **245** to cause the molten stream of material to follow the angular surface.

Figure 14 illustrates a plate **250** having a U-shaped orifice **251** comprising vertical open portions **252** which are connected together by a semiannular slot **253** providing a true U-shape for the orifice. A depending tongue **255** formed on the plate **250** is slanted downwardly and rearwardly as in the other forms of the invention. The plate **250** is formed with a projection or wall **256** for modifying the path of the induced air stream in a manner and for the purposes herein explained in connection with other forms of apparatus of the invention.

In the form of the invention shown in Figure 16 the blast orifice **261** in the front plate **262** is a rectangular opening **263**, which preferably is substantially square, having elongated slots **266** extending upwardly and outwardly from the two upper corners thereof. An extension **267** of the plate **262** affects the stream of induced air in the manner previously described. This form of orifice provides a greater depth of attenuating blast in the zone where the stream of molten material drops into the blast.

The orifice plates or members for determining the shape of the blast when adapted for use with an internal combustion burner for producing an intensely hot blast are constructed with cooling chambers of the general character illustrated in Figures 6 and 17. When the orifice plates are intended for use with steam or air blasts where the operating temperatures are relatively low, the use of the cooling chambers may be dispensed with.

In the utilization of the several forms of orifice plate provided with the slanted surface and air stream diverting means for establishing a zone of reduced pressure adjacent the slanted surface, the influence of the arrangement on the molten stream of material is such as to substantially eliminate a roving or spatial instability of the stream thus enhancing the efficiency of attenuation.

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 forming fibers from molten mineral material which includes establishing a high velocity blast; of flowing a stream of molten mineral material into the blast; of directing the path of movement of induced air at one side of the blast toward the source of the blast whereby the induced air aids in moving the molten stream of material into the high velocity zone of the blast toward the source of the blast for continuously attenuating the stream of material into fine fibers, and of collecting the fibers in a zone remote from the blast.

2. A method of forming fibers from molten mineral material which includes establishing a high velocity blast of hot gases of a temperature above the attenuating temperature of the material; of flowing a stream of molten mineral material toward the blast; of establishing a zone of reduced pressure at one side of the blast whereby the molten stream of material is angularly diverted toward

the source of the blast into the zone of intense heat in the blast whereby the stream is continuously attenuated into fine fibers by the force of the blast.

3. A method of forming fibers from flowable fiber-forming material which includes establishing a high velocity blast; of flowing a molten stream of fiber-forming material toward the blast; and of establishing a zone of differential pressure adjacent to and at one side of the blast diverting the molten stream toward the origin of the blast whereby the blast engages the terminus of the molten stream and attenuates the same into fibers.

4. A method of forming fibers from flowable fiber-forming material including continuously burning a combustible mixture in a confined zone; of discharging the hot gases of combustion through a restricted orifice of U-shaped configuration to provide a high velocity blast; of restricting the flow of air induced by the blast at one side of the blast to establish a zone of reduced pressure adjacent the orifice; of flowing a stream of fiber-forming material toward the orifice and into the blast at the zone of reduced pressure whereby the blast attenuates the advancing stream of fine fibers, and of controlling the direction of movement of the gases of the blast to effect a confluence thereof to envelop the fibers in the blast during attenuation.

5. A method of forming fibers from flowable fiber-forming material including burning a combustible mixture in a confined zone; of discharging the hot gases of combustion through a restricted orifice to provide a high velocity blast; of flowing a stream of fiber-forming material adjacent a surface and into the blast; of establishing a pressure differential effective at one side of the blast adjacent the surface to convey the stream into the blast adjacent the orifice whereby the stream is attenuated into fibers, and of cooling the surface adjacent the stream to a temperature below that at which the stream will adhere to the surface.

6. A method of forming fine fibers from molten glass which includes burning a combustible mixture in a confined zone and discharging the burned gases through a restricted orifice to produce a high velocity blast of hot gases; of flowing a stream of molten glass toward the blast; of establishing a path of travel of an induced air layer set up by the movement of the blast in a direction to establish a zone of reduced pressure at one side of the blast and adjacent the orifice whereby the molten stream is biased toward the orifice in a direction whereby the blast bends the extremity of the stream through an obtuse angle to attenuate the same into fibers.

7. A method of forming fibers from heat softenable material which includes establishing a high velocity blast and discharging same through a restricted orifice; of flowing a body of heat softenable material toward the blast; of establishing a force at one side of the blast effective to convey the flowing body into the blast toward the orifice whereby the direction of movement of the extremity of the body is substantially reversed by the blast and the body transformed thereby into fibers.

8. A method of forming fine fibers from flowable fiber-forming material which includes burning a combustible mixture in a confined zone and discharging the burned gases through a restricted orifice to produce a high velocity blast of hot gases; of flowing a stream of fiber-forming material toward the blast; of establishing a force adjacent the orifice effective to convey the stream into the blast in a direction whereby the end zone of the stream is bent by the blast through an obtuse angle and transformed by the blast into fine fibers.

9. A method of forming fibers from heat softenable material which includes establishing a continuous high velocity blast; of introducing a molten stream of the material into the blast, and of biasing the stream in the direction of the source of the blast for establishing a snubbing point near the end of the stream from which the blast is effective to bend the stream through an

obtuse angle and continuously form fibers from the end of the stream.

10. A method of forming fibers from heat softenable material which includes establishing a continuous blast of intensely hot gases; of flowing a stream of molten material into the blast, and of establishing differential pressure at one side of the blast providing a snubbing point near the end of the stream from which the blast is effective to continuously draw fibers from the end of the flowing stream of molten material.

11. A method of forming fibers from flowable fiber forming material which includes establishing a high velocity blast of steam; of flowing a stream of the material toward the blast of steam, and of setting up a force effective at one side of the blast to continuously convey the stream into the blast in a direction with respect to the movement of the blast whereby the direction of movement of the stream is substantially reversed by the blast of steam and the stream transformed thereby into fibers.

12. Apparatus for forming fibers from a molten stream of material including, in combination, a chamber having a restricted orifice formed in a wall thereof; means for discharging a high velocity blast from the orifice, an abutment engaging the chamber wall and projecting laterally of the blast at one side thereof to modify air currents induced by the velocity of the blast to establish a zone of reduced pressure at one side of the blast adjacent the orifice; means for flowing a stream of fiber-forming material adjacent the orifice whereby the reduced pressure directs the stream into the blast adjacent the orifice.

13. Apparatus for forming fibers from a body of fiber-forming material, in combination, a member having an orifice formed therein; means for establishing a high velocity blast adapted for discharge through said orifice; said member having a wall portion angularly directed toward the orifice; means for forming a moving body of fiber-forming material; baffle means associated with the member and disposed at one side of the blast for directing the path of movement of air currents induced by the velocity of the blast to establish a force biasing the moving body of fiber-forming material toward the angularly directed surface into the blast adjacent the orifice.

14. Apparatus for forming fibers from a stream of fiber-forming material including, in combination, an internal combustion burner for producing a hot, high velocity blast of burned gases; a wall engaging the burner and having a substantially U-shaped orifice through which the burned gases are discharged; baffle means formed on the wall and extending laterally of the burner in the direction of the leg portions of the U-shaped orifice for establishing a zone of reduced pressure at one side of the blast adjacent the orifice; the wall having a surface portion angularly directed toward the orifice at the zone of reduced pressure, and a chamber formed adjacent said angularly directed surface adapted to receive a cooling medium for maintaining the surface at a temperature below the fusing temperature of the fiber-forming material.

15. Apparatus for forming fibers from a stream of fiber forming material including, in combination, an internal combustion burner adapted to burn a combustible mixture in a confined zone; a member secured to one end of the burner and having an orifice formed therein through which the burned gases are discharged from the burner to provide a hot, high velocity blast; said member being formed with a baffle portion extending laterally of one side of the burner for controlling the path of travel of currents of air induced by movement of the blast whereby a zone of reduced pressure is established adjacent the orifice at one side of the blast; said member being formed with an angularly disposed surface canted toward the orifice in a direction generally opposite to the travel of the blast at the zone of reduced pressure; said member having a passage formed therein adapted to receive a cooling fluid for maintaining the angularly disposed surface at a temperature below the temperature of the flowing stream of fiber forming material.

16. Apparatus for forming fibers from a flowing stream of fiber-forming material including in combination an internal combustion burner for producing a hot, high velocity gaseous blast; said burner having a restricted orifice for the discharge of the gases; a member secured to the burner and having a substantially U-shaped nozzle formed therein for imparting a U-shaped configuration to the blast as the gases move through the nozzle; said member being formed with a wall projecting transversely of the path of the blast at one side thereof to direct the path of air currents induced by the velocity of the blast into the trough of the blast formed by the U-shaped orifice whereby a stream of fiber-forming material is influenced by the air currents to flow into the blast at the nozzle in said member and is attenuated by the blast into fibers, and means for cooling the member to maintain the temperature thereof below that of the stream of material.

17. Apparatus for forming fibers from a molten stream of material including, in combination, an internal combustion burner for producing a high velocity blast of hot gases, said burner having a restricted orifice for the passage of the gases; a member secured to said burner and having a portion projecting laterally of the burner at one side thereof arranged to influence the direction of flow of air currents induced by the velocity of the blast to establish a zone of reduced pressure at one side of the blast adjacent the orifice; means for flowing a stream of fiber-forming material adjacent the member whereby the reduced pressure bends the stream to flow in a path substantially parallel with the member into the blast of hot gases, and means for cooling the member below the temperature of the stream of material.

18. Apparatus for forming fibers from a stream of fiber forming material including, in combination, an internal combustion burner for producing a hot, high velocity gaseous blast; said burner having a member secured to the forward end thereof and having a restricted orifice defining the contour of the blast; said member being formed with a portion extending upwardly of the burner and a portion angularly directed toward the orifice; means for directing a stream of fiber forming material adjacent the upwardly extending portion of said member; said upwardly extending portion being adapted to influence the direction of air currents induced by the velocity of the blast at the side thereof whereby the stream of fiber forming material is diverted toward the angularly disposed surface and into the gaseous blast, and means including a chamber formed in said member adapted to receive a cooling fluid for maintaining the temperature of the angularly disposed surface lower than that of the stream of fiber forming material.

19. Apparatus for forming fibers from fiber-forming material including, in combination, an internal combustion burner adapted to burn a combustible mixture to produce a hot, high velocity blast of burned gases; said burner having a member secured thereto and formed with an orifice through which the burned gases are discharged to provide the blast; said discharge orifice being of a configuration to form a blast of trough-like configuration, the walls of the orifice being convergently arranged to direct portions of the trough-shaped blast toward a zone of confluence; means for cooling the walls of the orifice; said member having a baffle portion extending upwardly of the burner for controlling the course traversed by the adjacent layer of air set up by the blast to establish a zone of reduced pressure above the blast and adjacent the orifice, and means for feeding a stream of molten fiber-forming material into the zone

of reduced pressure and into the blast adjacent the orifice whereby the molten stream is attenuated into fine fibers.

20. Apparatus of the character disclosed including, in combination, a combustion chamber adapted to burn a combustible fuel and air mixture to provide a blast of extremely hot gases moving at high velocity; an opening in the burner for the discharge of burned gases forming the blast; a member secured to the discharge end of the burner and having a U-shaped orifice forming a passage for the discharge of the blast therethrough; said member being formed with a chamber; said chamber adapted to receive a cooling fluid for maintaining the surfaces of the member at reduced temperature; baffle means extending upwardly from said member for controlling the movement of induced air established by the velocity of the blast whereby a zone of reduced pressure is set up adjacent the orifice above the blast; said member having a surface angularly disposed with respect to the direction of movement of the blast and arranged adjacent the zone of reduced pressure; said surface being slanted toward the orifice in a direction generally opposite the direction of movement of the blast, and means for feeding a molten stream of fiber-forming material through said zone of reduced pressure into the blast whereby the stream of material entering the blast is attenuated to fine fibers.

21. Apparatus of the character disclosed including, in combination, a combustion chamber adapted to burn a combustible fuel and air mixture to provide a blast of hot gases of combustion moving at high velocity; an opening in the burner for the discharge of burned gases forming the blast; a member secured to the discharge end of the burner and having a U-shaped orifice forming a passage for the discharge of the blast therethrough; said member being formed with a chamber arranged to receive cooling fluid for maintaining the surfaces of the member at reduced temperature; said member being formed with an upwardly extending baffle for directing the movement of induced air established by the velocity of the blast whereby a zone of reduced pressure is set up adjacent the orifice above the blast; said member being formed with an angularly disposed surface adjacent the zone of reduced pressure; said surface being slanted toward the orifice in a direction generally opposite to the movement of the blast; means for feeding a molten stream of fiber-forming material through said zone of reduced pressure into the blast; the walls of the leg portions of the U-shaped orifice being angularly convergent to direct the portions of the blast to a zone of confluence whereby the stream of material entering the blast is enveloped therein and attenuated to fine fibers, and means for collecting the fibers.

22. Apparatus for forming fibers from a molten stream of material including, in combination with a high velocity gaseous blast, a plate having an opening formed therein through which the blast is projected, the opening being generally of U-shaped configuration to impart a U-shaped cross-sectional configuration to the blast, the obverse surface of the depending tongue forming the U-shaped opening being slanted rearwardly with respect to the adjacent surface of the plate, and an upwardly extending abutment wall formed on the plate for influencing the movement of the air stream induced by the blast.

23. Apparatus for forming fibers from a molten stream of material including, in combination with a high velocity gaseous blast, a plate having an opening formed therein through which the blast is projected, the opening being generally of V-shaped configuration to impart a V-shaped cross-sectional configuration to the blast, the obverse surface of the depending tongue forming the V-shaped opening being slanted rearwardly with respect to the surface of the plate, means for flowing a stream of material across a wall of said opening, and an abutment associated with the plate for influencing the movement of the air stream induced by the blast for establishing a zone of reduced pressure adjacent the rearwardly slanted surface.

24. Apparatus for forming fibers from a molten stream of material including, in combination with a high velocity gaseous blast, a plate formed with a plurality of relatively small closely spaced openings disposed in convergingly arranged rows through which the blast is projected, the surface of the portion of the plate between the rows being slanted rearwardly relative to the frontal surface of the plate and in the direction of convergence of the rows, means for flowing a stream of material across the wall of said openings, said plate being formed with a laterally projecting portion for influencing the air stream induced by the blast for establishing a zone of reduced pressure adjacent the rearwardly slanted surface.

25. Apparatus for forming fibers from a molten stream of material including, in combination with a high velocity gaseous blast, a plate having a substantially rectangular opening formed therein through which the blast is projected, a portion of the plate adjacent one wall of the opening being slanted rearwardly relative to the frontal surface of the plate, means for flowing a stream of material across a wall of said opening, and an abutment associated with the plate for influencing the movement of the air stream induced by the blast for establishing a zone of reduced pressure adjacent the rearwardly slanted surface.

26. Apparatus for forming fibers from a molten stream of material including, in combination with a high velocity gaseous blast, a plate having an opening therein through which the blast is projected, said opening being substantially rectangular in shape with slots extending upwardly and outwardly from the two upper corners, a portion of the plate adjacent one wall of the opening being slanted rearwardly relative to the frontal surface of the plate, means for flowing a stream of material across a wall of said opening, and an abutment associated with the plate for influencing the movement of the air stream induced by the blast for establishing a zone of reduced pressure adjacent the rearwardly slanted surface.

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