

Aug. 23, 1960

D. KLEIST ET AL

2,949,632

APPARATUS FOR CENTRIFUGALLY FORMING FIBERS

Filed Oct. 27, 1958

6 Sheets-Sheet 1

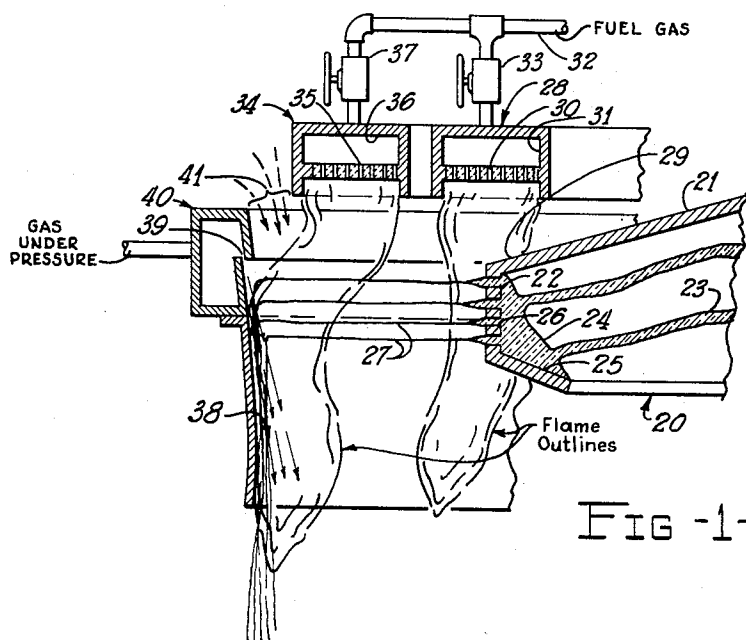


FIG -1-

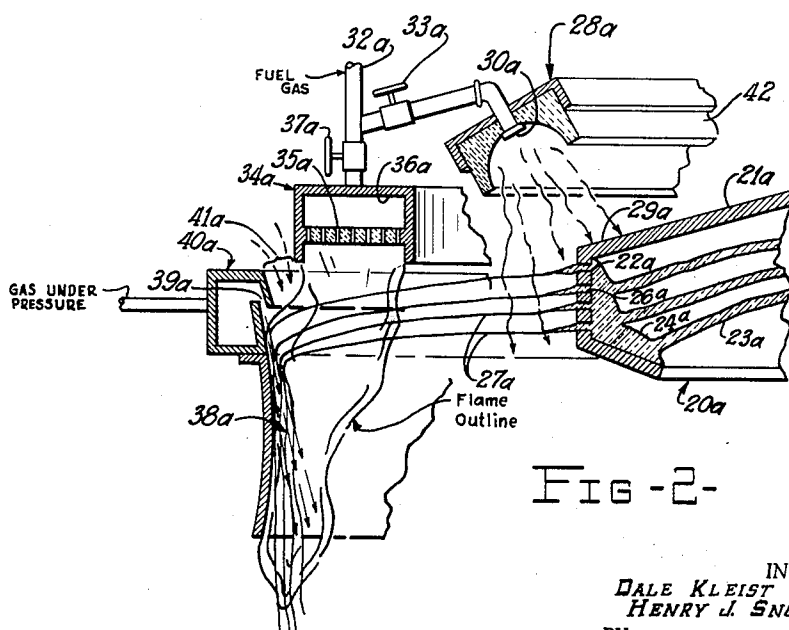


FIG -2-

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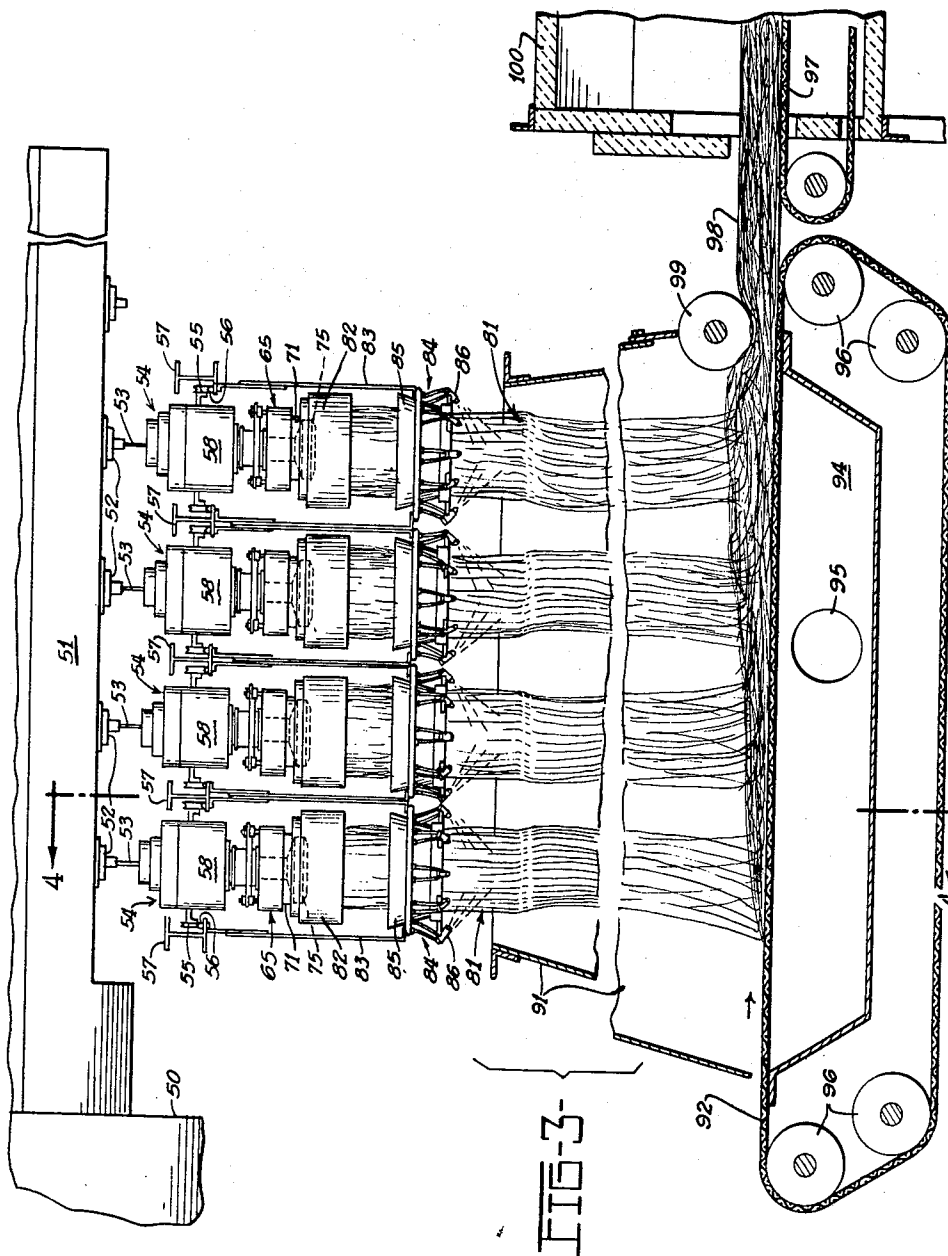
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APPARATUS FOR CENTRIFUGALLY FORMING FIBERS

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6 Sheets-Sheet 2



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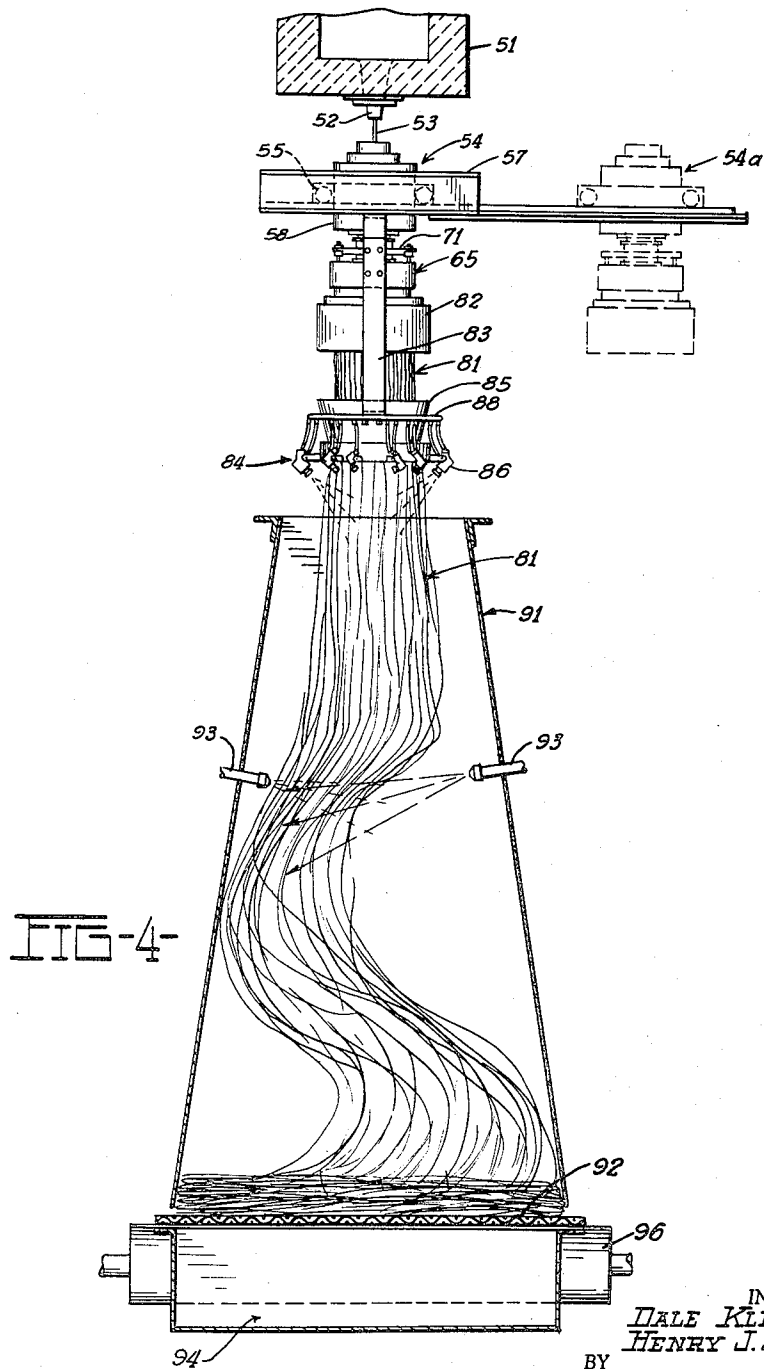
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APPARATUS FOR CENTRIFUGALLY FORMING FIBERS

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6 Sheets-Sheet 3



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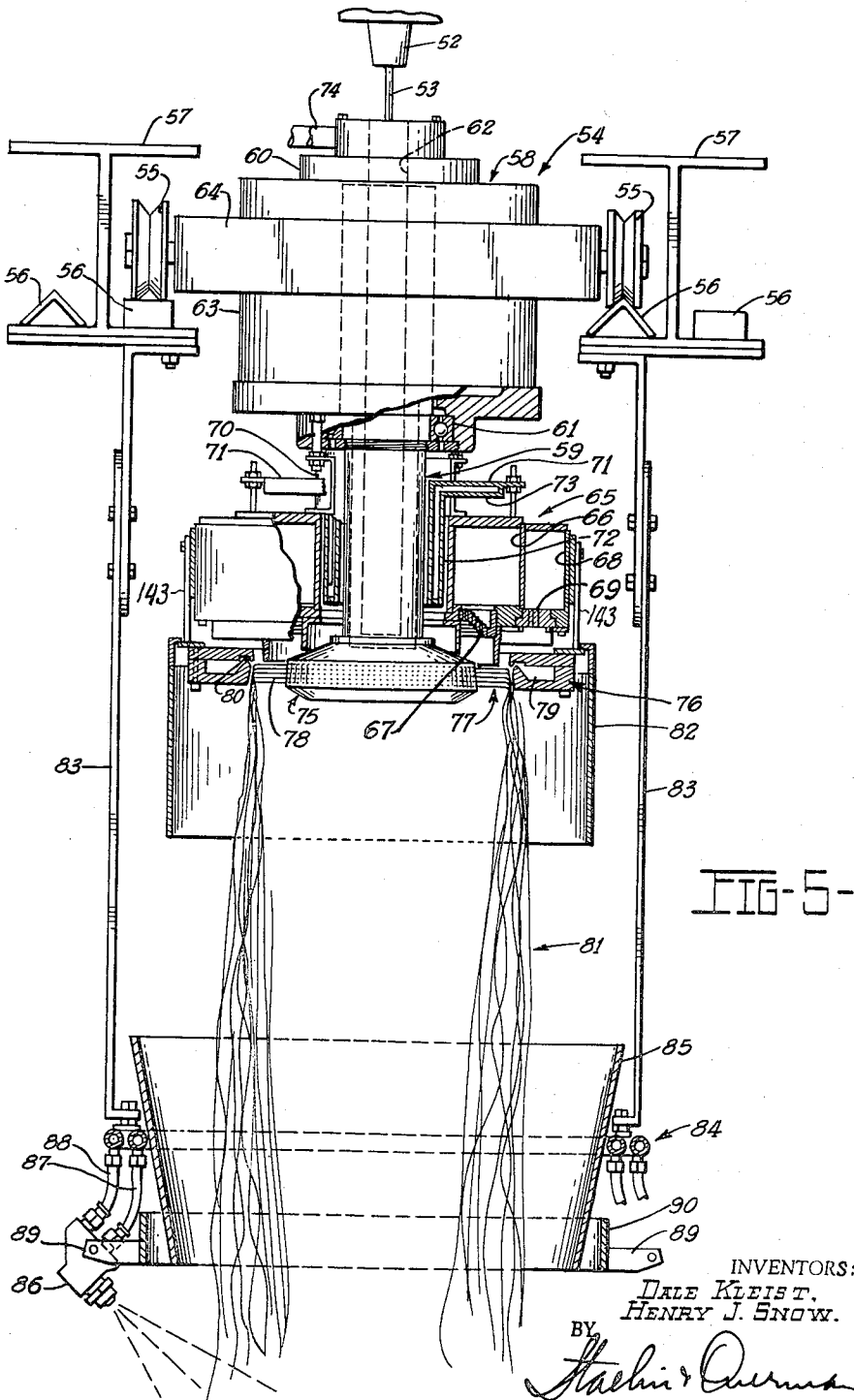
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APPARATUS FOR CENTRIFUGALLY FORMING FIBERS

Filed Oct. 27, 1958

6 Sheets-Sheet 4



Aug. 23, 1960

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APPARATUS FOR CENTRIFUGALLY FORMING FIBERS

Filed Oct. 27, 1958

6 Sheets-Sheet 5

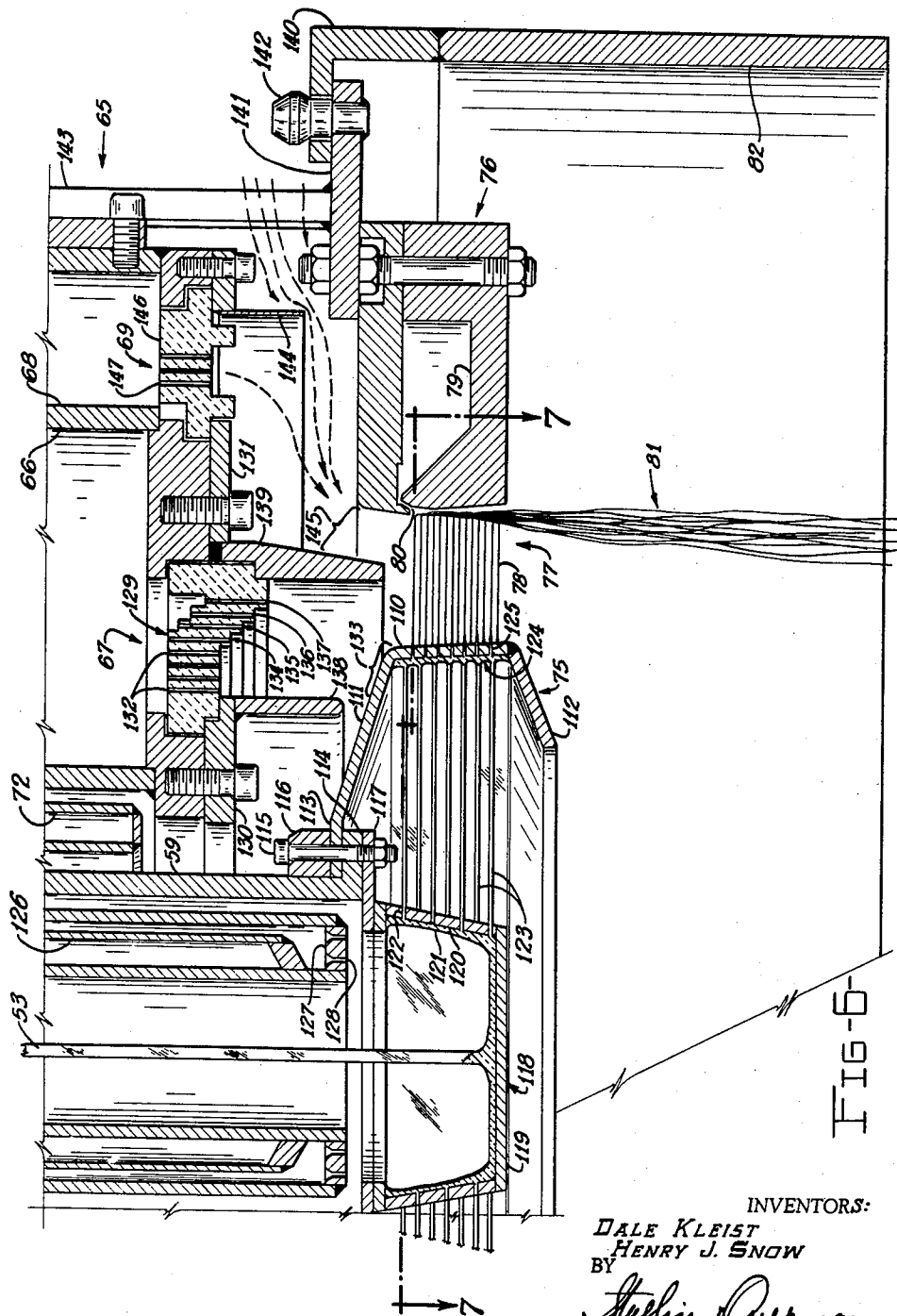


FIG-6

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APPARATUS FOR CENTRIFUGALLY FORMING FIBERS

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6 Sheets-Sheet 6

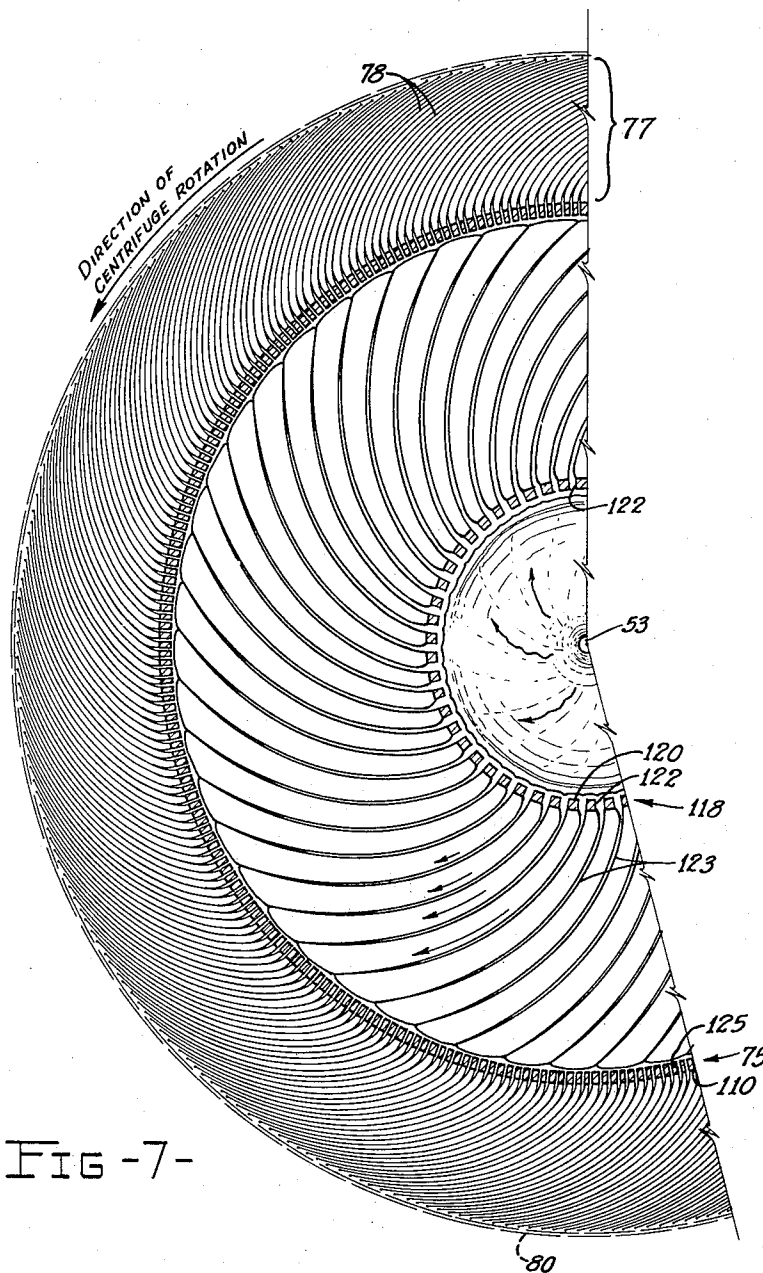


FIG-7-

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APPARATUS FOR CENTRIFUGALLY FORMING FIBERS

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Filed Oct. 27, 1958, Ser. No. 769,870

15 Claims. (Cl. 18—2.5)

This invention relates to apparatus for centrifugally forming fine fibers from fiberizable material, for example from heat softenable vitreous material, such as glass.

This is a continuation-in-part of our co-pending application Serial No. 594,803, which was filed June 29, 1956, now abandoned, and which will be referred to herein as "our previous application."

Our previous application disclosed and claimed a method and an apparatus for attenuating fine fibers from vitreous materials, i.e., from fiberizable materials such as glass, wherein a supply of molten glass is fed to a rotary centrifuge at a temperature at least sufficiently high for its attenuation into fine fibers by the kinetic energy from a blast of gaseous medium such as steam, into which the fiberizable material is projected in the form of streams issuing from the centrifuge, by centrifugal force created by the rotation of the centrifuge. The instant application is directed to apparatus which constitutes an improved embodiment of the apparatus disclosed and claimed in our earlier application. Concurrently herewith we are also filing an application directed to an improved method based upon the method of our earlier application as developed for commercial production and which also is based upon the teachings and disclosure of our earlier application.

The principal object of the instant invention is, therefore, to provide apparatus for the attenuation of very fine fibers of generally increased length from material of the class described wherein the material is projected from a rotary centrifuge at a temperature sufficiently high for attenuation into a high velocity blast of gaseous medium from an annular blower which surrounds the centrifuge and which has one or more heaters for the control of the temperature of the glass but which do not add heat to the glass after it first enters the centrifuge. Indeed, among the concepts underlying the instant invention is the control of the temperature of the glass by proper operation of the heaters in order to control its rate of heat loss so that its temperature continuously decreases from the time the glass first enters the centrifuge until it is finally attenuated into fine fibers; the apparatus of the invention being so designed and organized as to establish and maintain this close control of the temperature of the glass and thus its more effective attenuation into fine fibers of great length.

It is another object of the invention to provide improved apparatus for the formation of fine fibers by centrifuging fiberizable material into a gaseous attenuating blast by the combination of heaters designed and assembled according to the invention for the control of the environment into which the material is projected centrifugally and in which it is subject to the kinetic energy of the attenuating blast; this improvement including means for controlling the ambient air or other gases which are induced into the system by the eductor

effect of the expanding attenuating blast of gaseous medium.

It is yet another object of this invention to provide improved apparatus for the attenuation of fine fibers from heat softened fiberizable material wherein the control of the operation is enhanced by means for controlling the density of induced gases which enter the system and by means for controlling the manner and location of their entrance; the density being controllable by the presence of structural gas flow restricting means for reducing the quantity of the entering gases and/or by the use of a particularly located heater for increasing the temperature of the gases or, in the most improved process by doing both so as to most effectively control the attenuation and to produce the finest and longest fibers.

It is yet another object of this invention to provide improved apparatus for the attenuation of extremely fine glass fibers at high production rates which fibers have extreme length as well as fine diameters so that upon their compaction into a blanket like mass the mass has an extraordinarily high parting strength.

Other and more specific objects and advantages of the invention will be better understood by reference to the specification which follows and to the drawings in which:

Fig. 1 is a fragmentary, vertical, sectional view of a portion of rotary centrifuging apparatus embodying the invention;

Fig. 2 is a view similar to Figure 1, but showing a modification of the apparatus;

Fig. 3 is a view in elevation on a greatly reduced scale of a commercial fiber forming line including a plurality of apparatuses embodying an improved modification of the invention;

Fig. 4 is a transverse, vertical, sectional view taken along the line 4—4 of Figure 3 and shown on a slightly enlarged scale;

Fig. 5 is a fragmentary, vertical, sectional view of one of the apparatuses shown in Fig. 3, on an enlarged scale;

Fig. 6 is a fragmentary, detailed, vertical, sectional view of a portion of the apparatus shown in Figure 5, and

Fig. 7 is a fragmentary, horizontal, sectional view taken generally along the line 7—7 of Figure 6.

Preliminarily to the description of the particular figures of the drawings and an explanation of how the apparatus shown therein is operated, the operation carried out on the apparatus and its improved results will be discussed.

The apparatus constituting the invention in its simplest form comprises a rotating centrifuge into which the fiberizable material, for example glass, is fed. The fiberizable material is fed into the centrifuge from a glass tank forehearth or other source which heats it to a temperature well above the lowest temperature at which it can be attenuated. The entry temperature will, of course, vary, depending upon the constituents of the particular glass which is employed but will be above the liquidus temperature thereof. Using presently available commercial glass, this entry temperature is from about 1800° F. to about 2000° F. The centrifuge has a drive mechanism for rotating it at sufficient speed so that centrifugal force immediately causes the glass to flow radially outward in the centrifuge and to accumulate in an annular body on the inner wall of the periphery of the centrifuge.

In the apparatus embodying the invention the centrifuge has a generally cylindrical periphery with a multiplicity of orifices drilled therethrough, the orifices being arranged in, say, from one to ten or more vertically spaced, circumferential rows, and functioning to divide the glass body and to form it into streams of molten glass, the glass being forced through the orifices and projected out-

wardly therefrom as streams by the centrifugal force created in the annular body of glass by rotation of the centrifuge. While it might be said that these glass streams are projected radially outward from the centrifuge, it will be appreciated, of course, that in plan view the streams do not extend radially but are swept backwardly due to the ever increasing radius of each outwardly thrown particle of glass without, of course, compensatory increase in the angular velocity of these glass particles. As a result, and in common with all centrifuging operations, of course, the streams of glass sweep outwardly from the margin of the centrifuged body in helices as can best be seen by Figure 7 of the drawings in this application.

According to the invention the temperature of the glass is initially high enough so that the glass can be attenuated without the addition of further heat thereto, and the apparatus of the invention does not have means for adding heat to the glass after it first enters the centrifuge. Instead, it is one of the improvements of the instant invention to provide means for so controlling the environment into which the streams are centrifugally projected from the centrifuge that heat will continue to be lost from the glass during its progression through the system but at a rate substantially lower than the rate of heat loss which would occur if the environment were not controlled according to the invention. This control may be spoken of as retarding the rate of heat loss from the streams or as retarding the heat loss at a controlled rate by heating the gaseous environment in such a way as to maintain the temperature of that environment at such level that heat is not added to the glass during its passage through the environment and yet that heat is not lost to the environment from the glass at such a rate that the temperature of the glass streams will drop so rapidly as to fall below the attenuating temperature of the particular glass used prior to the attenuation of the streams into fibers by the kinetic energy of the blast of gaseous medium.

The invention also includes the provision of means for the control of ambient gases. In common with all expanding jets of gaseous media, the annular blast of gaseous medium delivered from a blower arranged around the centrifuge according to the invention, has a strong eductor effect and it induces a large volume of gases into the system. These gases may be ambient air, or other gases, and they may include the products of combustion of heaters which are provided according to the invention for exercising control, not only over the rate of heat loss of the glass itself, but also over the quantity or mass of the induced gases which enter the system. The invention contemplates also the provision of means for controlling the actual mass of the gases induced by restricting the space through which it is flowed and thus quantity of gases introduced and, further, the provision of means for limiting the induction of the induced gases to a certain location in the system whereby any deleterious effect of their induction is eliminated and the kinetic energy and/or heat possessed by the induced gases contributes to the actual attenuating process.

The foregoing explanation is intended not only as introductory to the following specific description of apparatuses embodying the invention, but also to correlate terms to be employed in such description and in the claims appended hereto as transferred from our earlier application and as first submitted herewith.

Figure 1 of the drawings is a diagrammatic showing of an apparatus embodying the invention in its more elementary concepts as disclosed and claimed in our earlier application, which, in its commercial form, is better shown in Figures 3-7 of the drawings.

In Figure 1, the elements of apparatus according to the invention include a rotary centrifuge generally indicated at 20 which has an upper conical wall 21 leading to a vertical quill (not shown) which supports the centrifuge 20 and which is driven at high rotary speed, for example, by an electric motor. The centrifuge 20 may also in-

clude any one of several types of glass distribution means so that a stream of glass fed downwardly through the quill and into the centrifuge 20 is distributed over the inner face of a peripheral wall 22 of the centrifuge 20. In Figure 1, heavy glass streams are diagrammatically shown at 23 as being thrown outwardly from a glass distributor (not shown) and accumulating in an annular body 24 against the inner surface of the wall 22 and a return lip 25 of the centrifuge 20. Because of the rotation of the centrifuge 20, the annular body 24 of glass is rotated and centrifugal force causes the glass to flow through a plurality of stream-forming orifices 26 drilled in the generally cylindrical peripheral wall 22 of the centrifuge 20. It will be appreciated, of course, that the particular configuration of the separated glass streams 23, the body 24, and streams of glass 27 projected through the orifices 26 are illustrative only and are not drawn with any attempt at a high degree of accuracy.

The streams 27 projected outwardly through the orifices 26 are attenuated somewhat in diameter although, of course, remaining highly fluid according to the invention and the control inherent in the arrangement of structure and the cooperation between the structural elements thereof as will be described below.

A first annular heater 28 is located above the peripheral portions of the centrifuge 20 which term includes both the peripheral wall 22 and a peripheral shoulder generally indicated at 29 on the conical return wall 21 of the centrifuge 20. The annular heater 28 is illustrated in Figure 1 as being a gas burner and as having a plurality of concentric rows of gas jet orifices 30 through which a combustible mixture of fuel, gas and air flows from a manifold 31 which is fed from a supply line 32 under control of a valve 33. As is roughly illustrated in Figure 1, heat from the first annular heater 28 (indicated by the legend "Flame Outline"), is directed downwardly on the peripheral shoulder 29 and the outer face of the peripheral wall 22 of the centrifuge 20 and to a first zone circumjacent the centrifuge 20 through which the streams 27 are projected by centrifugal force. While the flame outline from the first annular burner 28 is shown in Figure 1 as having a definite border, this is, of course, not accurate and only generally indicates the zone to which heat is applied from the first annular heater 28.

In the embodiment of Figure 1, there is also a second annular heater 34. The second annular heater 34 is also a flame burner and is substantially identical with the inner annular heater 28, although constructed upon a larger radius and thus being radially spaced exteriorly of the first annular heater 28. Like the first, or inner, annular heater 28, the second or outer heater 34 has a plurality of jet orifices 35 fed from a common manifold 36 which is under the control of a separate valve 37 so that each of the two heaters 28 and 34 may be independently controlled. This independent control of the two concentric and radially spaced annular heaters 28 and 34 constitutes an important facet of the instant invention and makes possible control of the environment through which the streams 27 are projected, both in a first zone or environment adjacent the centrifuge 20, and in a second zone or environment radially exteriorly of the first zone and comprising the zone of attenuation wherein the streams 27 are attenuated into fibers. As with respect to the "Flame Outline" of the heater 28, the "Flame Outline" of the heater 34 is also only illustrative. While heat from the two heaters 28 and 34 may blend together at the central portion of the annular space across which the streams 27 are projected, nevertheless each of the two concentric heaters 28 and 34 has independent control and the temperature conditions in the two zones or environments may be separately established and maintained by this combination of apparatus.

In apparatus designed according to the invention the streams 27 are attenuated by an annular blast, indicated by the reference number 38 in Figure 1, which is directed

downwardly from an annular orifice 39 of a blower 40. The blower 40 is concentric with and spaced radially from the centrifuge 20. The annular orifice 39 may continue unbroken around the entire blower 40 or it may be formed by a plurality of separate minute orifices, which might be considered to be short slots. In either case, of course, the blast 38 is circumferentially continuous.

The blast is referred to herein as an "attenuating blast" or as an "expanding blast," the first relating to its function, and the second to one of its physical characteristics. In general the blast must have sufficient kinetic energy so that it will be able to attenuate the glass. This is determined, of course, by the pressure maintained in the blower 40 and by the area of the orifice 39 through which it is directed. The attenuating blast must also be at a temperature which is controlled at a level substantially above ambient temperature but substantially lower than the temperature maintained in the space between the centrifuge 20 and blower 40. The temperature of the blast must not chill the system as a whole but it must be low enough so that the glass will rapidly cool after it is attenuated into fibers.

Inherent in the operation of any such expanding jet as a blast of steam or other gaseous medium emitted from a constricted orifice such as the orifice 39, there is an eductor effect which induces large volumes of gases into the system. In fact, the instant invention includes within its concepts, the provision of means for the deliberate induction of gases and their utilization in the operation and in achieving the highly refined attenuation of long fine fibers according to the invention. In the construction illustrated in Figure 1, the eductor effect of the blast 38 induces ambient air over the top of the blower 40 through a space which might be called an orifice, and which is generally indicated by the reference number 41, and into the annular space through which the streams 27 are projected by centrifugal force. The instant invention includes among its concepts means for the control of its operation by control of the induced gases.

In the apparatus illustrated in Figure 1, these gases would be merely induced ambient air. The outer or second annular heater 34 is so positioned relative to the blower 40 that it functions with the blower 40 to define the induction orifice 41 and heat from the heater 34 is directed across the path of the induced gases to raise their temperature prior to their entry into the system. The effect of controlling both the quantity and the temperature of the induced gases by the apparatus of the invention will be more fully explained below with respect to the embodiment of the invention on a commercial scale, which apparatus is illustrated in Figures 3-7.

Although the legend "Flame Outline" is used in Figure 1, the area delineated by each is not one in which flame alone is present nor one in which the glass is subject to heating by a flame at usual flame temperature. For example, in the "Flame Outline" area of the second or outer heater 34, the ambient air induced over the blower 40 blends with the burning gases from the heater 34 throughout this zone in order to establish the controlled environment at this point in the system. In both of the so-called "Flame Outline" areas, the temperature is such that the glass temperature is not increased during passage of the streams therethrough.

While the eductor effect of the blast 38 is not specifically commented upon in our earlier application, and the broken arrows indicating the flow of ambient induced gases through the orifice 41 are not shown therein, the eductor effect is inherent in any such blast and the positioning of the second annular heater 34 in the position shown in Fig. 1 (Fig. 2 of our earlier application) establishes quantitative control over these induced gases.

In the instant specification, control over the induced gases is explained and included as a part of the improved operation resulting from the combination of the inven-

tion from two standpoints—(a) their temperature and (b) their quantity. Control of the temperature and/or quantity of the induced gases results in control over the density of the induced gases, and since the kinetic energy of gases may be expressed as

$$\frac{mv^2}{2}$$

it can be seen that the mass of gas induced plays an important part in the process. Since the mass of induced gases depends upon their temperature and volume, it follows that control of temperature and/or quantity results in control of the kinetic energy and heat added to the system by the induced gases according to the invention.

In Figure 2 of the drawings, there is shown a centrifuge 20a similar to the centrifuge 20 shown in Figure 1, a first inner annular heater 28a corresponding to the first annular heater 28 in Fig. 1, a second annular heater 34a which is radially spaced exteriorly of the first heater 28a and which corresponds to the second heater 34 of Fig. 1, and a blower 40a corresponding to the blower 40 of Fig. 1. In the modification of the invention illustrated in Fig. 2, the first annular heater 28a is a gas fired, radiant heater and has a domed ceramic 42 which is heated by a plurality of gas jets 30a spaced circumferentially around the heater 28a and which are fed with a combustible mixture from a supply line 32a under the control of a valve 33a. The second annular heater 34a is similar in all respects to the annular heater 34 of Fig. 1 and like the heater 34 has a plurality of jets 35a fed from a common manifold 36a under the control of an independent valve 37a. As in the apparatus shown in Fig. 1, the centrifuge 20a of Fig. 2 has a peripheral wall 22a through which there are drilled a plurality of stream forming orifices 26a and the upper conical wall 21a has a peripheral shoulder portion 29a. Glass which is flowed into the centrifuge 20a is distributed in hot streams 23a over the interior of the peripheral wall 22a forming an annular body 24a thereagainst. Relatively heavy glass streams 27a are projected outwardly through the stream forming orifices 26a across the annular space between the peripheral wall 22a of the centrifuge 20a and a blast 38a fed from an annular orifice 39a of a blower 40a.

Although the relative vertical levels of the centrifuge 20 and blower 40 of Figure 1 differ from the relative vertical levels of the centrifuge 20a and blower 40a of Figure 2, this difference is not intended as being restrictive of the invention. The vertical level between these two pieces of apparatus, each of which functions to carry out at least one of the steps of the method embodying the invention, is critical only to the extent that the blower 40 or 40a must be so positioned vertically relative to the centrifuge 20 or 20a that the streams 27 or 27a will be projected outwardly and into the respective blast 38 or 38a at a level below the respective orifice 39 or 39a. It is apparent, of course, that if the relative vertical levels of the centrifuges and blowers were such that the streams would be projected either against the blower housings or into the blast at a point far removed from the blast forming orifice, the glass in the streams would, in the first instance, collect on the housing, or, in the second instance, not be effectively attenuated because the expansion of the blast would have reduced its kinetic energy to a point below that necessary for attenuation.

In the modification illustrated in Figure 2, as in that shown in Figure 1, the two annular heaters 28a and 34a have independent controls; the inner heater 28a functioning to apply heat to the first zone of the gaseous environment through which the streams 27a are projected, and thus to reduce the rate of heat loss from those portions of the streams as well as from the rotating annular body 24a. This first zone thus includes both the rotating

annular body and portions of the streams projected centrifugally from it. Again, as in the case of the modification shown in Fig. 1, the second annular heater 34a, which is radially spaced exteriorly of the first heater 28a, functions to apply heat to the outer part of the annular space through which the streams 27a are projected for the purpose not only of controlling the rate of heat loss from the streams therein, but of controlling the environment in that second zone which includes the zone of the blast 38a. In addition, as in Figure 1, heat from the second annular heater 34a raises the temperature of gases which are induced over the corner of the blower 40a and through the orifice generally indicated by the reference number 41a, to approximately the level of the blast 38a.

The inner annular heater 28 or 28a of the modifications shown in both Figures 1 and 2 is provided to the invention to control the temperature not only of portions of the streams 27 and 27a, but of the rotating annular bodies 24 and 24a of glass from which the streams are formed. It will be appreciated that in any such centrifuging structure, heat brought into the system by the admitted molten glass is transferred by conduction, convection and radiation to all structural elements in the system and to the atmosphere surrounding the structure. A large quantity of heat is transferred directly to the body of the centrifuge 20 or 20a itself. Heat flows upwardly along the conical walls 21 and 21a of these centrifuges to the quills (not shown) on which they are mounted for rotation. The flow of heat upwardly along these conical walls 21 and 21a is substantial because in any structure of this type it is necessary to jacket the quills, for example, with cold water jackets, to prevent damage to the bearings upon which they are mounted and a substantial heat flow from the centrifuge results. If no heat control were exercised in the system, great quantities of heat would be lost from the glass to the centrifuge and eventually to the water jackets. Thus, the inner annular heaters 28 and 28a are provided according to the invention to replace the heat lost from the glass to the centrifuge and the connected apparatus, and thus to control the rate of heat loss from the glass in the annular bodies 24 and 24a, reducing the heat loss from those bodies to a rate substantially lower than that which would prevail were it not for the first annular heaters 28 and 28a.

Simultaneously, the first annular heaters 28 and 28a apply heat to the inner part of the annular space between the centrifuges 20 or 20a and the blasts 38 and 38a in the first zone thereof so as to heat the first environment into which streams are projected so that its temperature is maintained at a level such that the rate of heat loss from the streams is also retarded. The temperature level at which the first environment is maintained depends, of course, upon the entire operation but may be defined as being below a temperature which would add heat, i.e., raise the temperature of the streams, and above a temperature at which heat lost from the streams to the environment would so cool the streams as to reduce their temperature to a level below the attenuating temperature of the particular glass being fiberized before the streams are attenuated by the attenuating blasts 38 and 38a.

The second annular heaters 34 and 34a, which are radially spaced exteriorly of the first heaters are provided, according to the invention, to control the rate of heat loss from the outermost portions of the streams by controlling the environmental temperature of the second zone above described and they also act to control the induced gases, at least in part. Were these gases to be induced at ambient temperature, they would rob heat from the system and from the streams, so reducing the temperature of the streams as possibly to prevent their attenuation into the very fine and long fibers which are produced on apparatus of the invention. In addition, the exterior annular heaters expand the induced gases and thus reduce their mass per unit of volume and thus reduce

the kinetic energy of these gases to a controlled level, so that they do not interfere with the clean entry of the streams 27 and 27a into the expanding attenuating blasts 38 and 38a.

The control of the induced gases which is spoken of herein as either involving a reduction of their density, an increase of their temperature or a reduction of their volume or mass, might lead to the suggestion that the presence of induced gases is completely undesirable and, thus, to the suggestion that the induction of gases into the system should, if possible, be entirely prevented. This is not the case. Any expanding jet is accompanied by an eductor effect which, if not at least partially satisfied, causes the jet or blast to plume or expand much more rapidly than would otherwise take place as the gases of the jet whirl and eddy upwardly to satisfy the vacuum created by the blast. It can be seen in Figures 1 and 2 that if the blasts were not supplied with at least a substantial proportion of the gases required to satisfy their eductor effects, the gases of the blasts 38 and 38a would eddy inwardly and upwardly, creating substantial turbulence and eddy currents which would have several undesirable effects. First, since the direction of movement of these eddy currents would be contra to the direction of projection of the streams 27 and 27a, they would interfere with that projection. Secondly, the excessive pluming or expansion of the blasts would reduce their kinetic energy available for attenuation much more rapidly than if the blasts were kept relatively free of eddy currents. Thirdly, it is of critical importance that the temperature of the glass streams upon penetration into the central high speed portion of the blasts 38 and 38a shall be such that the blasts can attenuate the streams effectively into fine fibers. If the streams are chilled to too great a degree at the time of their entry into the attenuating blasts, as, for example, by an excessive chilling effect of cold induced gases or an excessive volume of induced gases, they are not attenuable to the degree possible if the temperature and mass of the induced gases are properly controlled.

The discussion of the effects of these various facets of a process carried out by operation of apparatus designed according to the invention is based upon the observation of experimental operation of such apparatuses wherein the various conditions are changed under control. Most effective production of fine glass fibers is accomplished when the apparatus is all operated to carry out all of the teachings of the invention. When only some of these teachings are put into effect, the results still represent substantial improvements in the degree of attenuation achieved and in the quality of the fibers produced by prior art methods and apparatuses. Each additional concept underlying invention which is added results in a further improvement. As an illustration, an apparatus substantially identical in its major parts with the apparatuses illustrated in Figures 1 and 2, but not incorporating any means for the control of ambient induced gases, may be able to attenuate fibers to average diameters in the order of, say, .00025 inch from streams of certain diameter and temperature projected at certain speeds. If means are then added for controlling and reducing the quantity of the induced gases so that the mass of the gas, and thus its kinetic energy is reduced, the fiber diameters will drop, say, to .00021 inch. If the second, outermost annular heater is then utilized to raise the temperature of the induced gases to, say, approximately the temperature of the attenuating blast, the diameter of the produced fibers will drop to as low as, say, .00016 to .00018 inch.

The desirability of these finer fibers becomes immediately apparent when the resulting insulating capability of a mass of the fibers produced is determined. In general, it may be said that for any given thickness and apparent density of glass fiber insulating mat, the insulating quality increases as the average diameter of the fiber

making up the mat decreases. It is thus desirable in commercial production to fabricate fibers as fine as possible and as nearly uniformly as possible, which objects are achieved by operation of the apparatus embodying the invention.

In addition and of equal importance, the commercial desirability of fine glass fibers increases in direct ratio to their lengths. The longer the fibers which are accumulated to form the mat, the greater the physical strength of a mat of given thickness and apparent density. Where short fibers, such as those produced by the operation of combustion products rotary apparatuses, are compacted into insulating mats, the parting strength is so low as to make the final product difficult to handle in use. In sharp contrast, masses of fine long fibers produced on the apparatus of the invention form insulating mats of considerable strength, capable of withstanding rough handling in their commercial uses. Parting strength is an expression of the force in pounds per unit of weight required to pull a sample apart. It is measured by fitting a doughnut shaped section of the material over two rods and pulling the rods apart until the sample separates into two pieces. For any particular apparent density and thickness of sample, the higher parting strength is indicative of longer, stronger and more nearly uniform fibers.

Apparatus embodying the invention and suitable for the commercial use is disclosed in Figures 3-7. This apparatus embodies the invention originally disclosed and claimed in our earlier application identified above and as modified and improved according to the teachings of the instant application for the achievement of practical commercial production. In the portion of this specification which follows, therefore, this apparatus will be described in detail and correlation between the apparatus set forth and the basic concepts inherent in our earlier application and described above, will be made.

Figure 3 shows a multiple unit, commercial set up, embodying the instant invention in all of its refinements. A glass tank 50 is fragmentarily shown as leading to an elongated forehearth 51. Molten glass suitable for attenuation into fine fibers is fed from the tank 50 and along the forehearth 51 above its liquidus temperature. Spaced along the forehearth 51 are four stream-forming bushings 52 each of which controls the discharge of a heavy stream of molten glass 53 into a fiberizing unit 54 embodying the invention. Each of the fiberizing units 54 is mounted by rollers 55 on a pair of transverse rails 56 which are supported by heavy cross beams 57. Each of the units 54 may be moved laterally away from the production line to the position indicated by the broken lines 54a (Fig. 4) when necessary for repair or modification.

Each of the production units 54 comprises a drive unit 50 which rotatably supports and drives a quill 59 (Fig. 5). The quill 59 is mounted for rotation by an upper bearing 60 and a lower bearing 61 and is tubular in shape, providing a vertical central opening 62 through which the heavy stream of glass 53 flows downwardly. The drive unit 58 has a cooling jacket 63 and is carried by heavy cross brackets 64 on which the rollers 55 are mounted.

The lower portion of the quill 59 extends downwardly through an annular heater unit generally indicated at 65 and comprising two concentric, annular manifold chambers, an inner chamber 66 for an inner heater 67, and an outer manifold 68 for an outer heater 69 which is radially spaced exteriorly of the first annular heater 67. The unit 65 is supported from the bottom of the drive unit 58 by a heavy tubular flange 70 and, in turn, adjustably supports a tubular water jacket 71. The water jacket 71 has a downwardly extending tubular portion 72 circumjacent a considerable length of the quill 59 and a horizontal flanged portion 73 extending outwardly across the space between the top of the burner unit 65 and the bottom of the drive unit 58. Coolant for the jacket 71 and the drive unit jacket 63 is carried

to and from the unit 54 by pipes 74 located at the upper part of the drive unit 58.

A rotary fiber forming centrifuge generally indicated at 75 is removably supported at the bottom of the quill 59 and an annular gaseous blower generally indicated at 76 is suspended from the heater unit 65 at the level of the centrifuge 75. The centrifuge 75 and the blower 76 bound an annular space, generally indicated at 77, across which streams of glass 78 are projected from the centrifuge 75. The blower 76 has a plurality of orifices 80 which extend circumferentially around its inner wall and through which a heated gaseous medium under pressure, such as steam, is fed from its interior manifold 79. The gaseous medium forms a downwardly moving, annular attenuating blast having high kinetic energy. The centrifuge 75 is rotated at such speed that the streams 78 are projected therefrom with sufficient force to penetrate the turbulent inner margin of the blast and into its high velocity central portion where the molten glass in the streams 78 is subjected to the force of the blast and attenuated into a plurality of very fine fibers of great length, the veil of fibers thus formed being generally indicated at 81. A heavy guard 82 surrounds the attenuating area, the guard 82 being removably supported by suitable brackets from the lower side of the burner unit 65.

Hanger straps 83 depend from the cross beams 57 and support a binder gun unit 84 beneath the centrifuging unit. The binder gun unit 84 comprises a guide 85 and a plurality of downwardly and inwardly directed binder spray guns 86 which are fed with air and suitable binder from supply pipes 87 and 88. The binder guns 86 are circumferentially spaced by brackets 89 around a ring 90 and are tiltable in the brackets 89 so that sprays of binder material may be directed inwardly onto the tubular veil of fine fibers 81 moving downwardly through the binder gun guide 85.

A hood generally indicated at 91 in Figures 3 and 4 is spaced below the units 54 and has an open upper end for the entry of the several veils of downwardly moving fibers 81 and a lower open end which closely overlies an accumulating conveyor 92. The veils 81 are lapped back and forth in the hood 91 for accumulation on the conveyor 92 by the action of a pair of alternately energized air jets 93 (Fig. 4) located at opposite sides of the hood 91, there being a pair of jets 93 for each of the units 54 and thus each of the veils 81. By transversely lapping the veil of fibers 81, they are built up in ever thickening layers upon the forwardly moving conveyor 92. The large volume of gases carried downwardly into the hood 91 is exhausted through a chamber 94 which extends beneath the conveyor 92 and is connected by a suitable duct 95 to exhaust blowers (not shown). The conveyor 92 preferably is fabricated from link chain or similar material so that the gases will readily pass through the conveyor 92 into the exhaust chamber 94. The conveyor 92 is mounted upon and driven by a plurality of conveyor rollers 96 and closely abuts the receiving end of a furnace conveyor 97 (Fig. 3). An accumulated blanket 98 of fibers is carried out of the hood 91 by the receiving conveyor 92 and compacted somewhat by a pressure roller 99 at the outlet side of the hood 91. The blanket 98 is carried by the furnace conveyor 97 through a furnace 100 in which the binder applied to the veils of fibers 81 from the binder gun units 84 may be set up to hold the blanket 98 in a desired controlled thickness, or apparent density.

The portions of the commercial apparatus illustrated in Figs. 3-7 which correspond to the apparatuses shown in Figs. 1 and 2 are shown in detail in Figs. 6 and 7. The centrifuge 75 has a peripheral wall 110 which is illustrated in Fig. 6 as being slightly conical in shape but which might also be formed as a cylinder or coned in the opposite direction, all three shapes being included in the terminology "generally cylindrical." The periph-

eral wall 110 is integral with and supported by a conical, flanged, top wall 111 and has an inwardly directed, conical return lip 112. At the upper, inner edge of the conical wall 111 the centrifuge 75 has a turned over annular lip 113 by which it is supported on an outwardly directed flange 114 at the bottom of the quill 59. The centrifuge 75 is mounted on the quill 59 by a plurality of mounting bolts 115 which extend through a mounting ring 116, the flange 113 of the centrifuge 75 and the flange 114 of the quill 59. The bolts 115 also extend through an outwardly directed flange 117 which supports a cup-shaped distributor generally indicated at 118.

The distributor 118 is illustrated in the drawings as having an imperforate bottom 119 and an outwardly flared, circular side wall 120. The molten glass stream 53 drops downwardly by gravity through the hollow quill 59 and against the bottom 119 of the distributor 118. Since the distributor 118 is mounted on the quill 59 with the centrifuge 75, centrifugal force causes the glass from the stream 53 to flow radially outward across the bottom 119 (see also Fig. 7) and against the inner surface of the wall 120. A relatively thick layer of glass indicated at 121 forms on the inner surface of the wall 120. The wall 120 is perforated with a substantial number of large diameter orifices 122 through which glass from the layer 121 is centrifugally thrown as heavy distribution streams 123.

Glass in the distribution streams 123 impinges against the inner surface of the peripheral wall 110 of the centrifuge 75 and re-combines to form an annular body of glass generally indicated at 124. The peripheral wall 110 of the centrifuge 75 is perforated by a very large number of minute orifices 125 through which centrifugal force flows glass from the body 124 and from which streams 78 of the molten glass are projected outwardly across the annular space generally indicated at 77. The outwardly projected streams of molten glass 78 are projected with such force as to enter but not go through, i.e., to penetrate through the turbulent margin and enter into the interior high velocity portion of the blast of gaseous medium delivered downwardly from the annular orifices 80 of the blower 76. In the commercial embodiment of apparatus for carrying out the process of the invention as practiced in the structure illustrated in Figs. 3-7, the blower 76 employs steam under pressure. The kinetic energy of the steam attenuates the heavy streams 78 into fine, long fibers directing them downwardly in the hollow veil 81.

The quill 59 has an internal water jacket 126 which cooperates with the tubular portion 72, of the jacket 71 in order to prevent the flow of heat from the centrifuge flange 113 upwardly along the quill 59 which would, of course, damage the bearings 61 and 62 and the motor of the drive unit 58. In addition, interiorly of the quill 59, there is a small burner 127 having a few flame orifices 128 that are directed downwardly into the interior of the distributor 118. The burner 127 is not fired during the normal operation of the apparatus of the invention but is employed at the time of initial start-up in order to pre-heat the distributor 118 so that it will not excessively chill the molten glass in the stream 53 when it is first admitted thereto. Because the glass in the stream 53 is at its highest temperature when it first enters the apparatus, the distributor 118 quickly reaches a high enough temperature and is thereafter kept hot by new glass so that the internal burner 127 is no longer necessary. It is, therefore, turned off a few minutes after the operation is initiated.

Apparatus designed according to the invention controls the temperature of the glass in the body 124 and in the streams 78 as they are projected across the annular space 77 by means of the inner annular heater 67 and outer annular heater 69, as discussed above in connection with Figs. 1 and 2. The inner burner 67 is fed with a combustible mixture of gas and air from its manifold 66. The burner 67 has a stepped orifice plate 129 which is

fabricated from refractory material and is mounted at the bottom of the manifold 66 by retaining rings 130 and 131. The orifice plate 129 has several concentric, circular rows of orifices indicated as a group by the reference number 132 all of which are formed in a horizontal portion of the orifice plate 129 and all of which are positioned vertically above a shoulder portion 133 of the centrifuge 75, indicated by the bracket in Fig. 6. The orifice plate 129 and the several rows of orifices 132 are spaced above the shoulder portion 133 of the centrifuge 75 a distance such that the hottest parts of the flames burning from the orifices 132 are located at or very close to the surface of the shoulder portion 133.

The orifice plate 129 in the apparatus shown in the drawings also has several, downwardly stepped, concentric, circular rows of orifices 134, 135, 136 and 137. Each of the rows 134-137, inclusive, is stepped downwardly such a distance from its predecessor that the total of all of the distances is approximately equal to the vertical dimension of the peripheral face 110 of the centrifuge 75. The flames burning from the orifices in each of the successive rows 134-137, therefore, have their hottest parts staggered or stepped downwardly adjacent the face 110 to achieve nearly uniform heat application over the entire face 110.

The heating zone of the inner heater 129 is defined and heat from its flames directed into the first zone of the annular space 77 by a pair of air direction rings 138 and 139. The inner air direction ring 138 functions to greatly restrict the flow of induced gases downwardly around the quill 59 or between the quill 59 and the water jacket 72, or inner wall of the manifold 66, so as to reduce as much as possible any effect that gases entering the system from this point would have upon the temperature and forces present in the annular space 77, and to prevent the flow of hot combustion gases from heater 129 upwardly around the quill 59.

The outer air direction ring 139 is a part of the apparatus provided for induced gas control according to the invention. The attenuation guard 82 is supported from the burner unit 65 by a support ring 140 removably held in place on an annular flange 141 by removable pins 142. The flange 141 depends from several mounting bars 143 which are secured to the burner housing 65. (See also Fig. 5). An open space indicated by the broken arrows in Figure 6 is thus provided through which ambient air is directed into the space above the blower 76 and below the burner unit 65. An air limiting ring 144 extends part way across this space to limit the flow of gases therethrough and an induced air orifice 145 is formed by the inner upper corner of the blower 76 and the outer side of the air control ring 139. The second, or outer, annular heater 69 has an orifice plate 146 in which there are formed several rows of orifices 147. A combustible mixture of gases from the manifold 68 of the heater 69 is fed through the orifices 147 at such rate as to heat air induced into the space above the blower 76 to a temperature approximating the temperature of the attenuating blast emitted from the orifices 80 of the blower 76. The combustion gases from the outer heater 69 are induced to flow with the ambient induced air through the air control orifice 145 and downwardly into the annular space 77 where their heat and kinetic energy cooperate with the attenuating blast to control the temperature and attenuation of fibers from the streams 78.

We claim:

1. Apparatus for the attenuation of fine fibers from heat softenable vitreous material, said apparatus comprising a metallic centrifuge and means for rotating the same, means for supplying flowable softened material to said centrifuge, said centrifuge having a plurality of stream forming orifices in its periphery, a first annular heat source located externally of and near the periphery of said centrifuge for applying heat to a zone including the periphery of said centrifuge for retarding heat loss

from the material therein and from material issuing from the orifices as streams and to at least a part of said streams, means for controlling said annular heat source, a second annular heat source located radially exteriorly of the first said heat source and spaced radially therefrom for applying heat to a second zone radially exterior of said first zone and including at least a part of the length of said streams where the diameters are being reduced by attenuation to fibers for retarding the rate of heat loss therefrom, means for controlling said second heat source independently of said first heat source and an independently controlled annular blower located radially exteriorly of said first heat source for applying tractive forces to fibers attenuated from said streams, one of said heat sources and said blower defining therebetween an annular passageway open outwardly to the surrounding atmosphere for the flow of gases induced there-through by said blower.

2. Apparatus according to claim 1 in which the first heat source is a burner having a flame playing in the first zone.

3. Apparatus according to claim 2 in which at least one of said heat sources is a source of radiant energy.

4. Apparatus for the attenuation of fine fibers from streams of hot glass projected outwardly by a centrifuge, said apparatus comprising, in combination, a first annular heat source concentric with, external of and located near the periphery of said centrifuge for applying heat to a zone including the periphery of said centrifuge for retarding the rate of heat loss from said glass streams issuing therefrom as streams and to at least the first part of said streams, means for controlling said annular heat source; an independently controlled annular blower concentric with and spaced exteriorly of said heat source for directing a high velocity blast of gaseous medium to apply tractive forces to fibers attenuated from said streams, a second annular heat source spaced radially outwardly from the first said source for applying heat to a zone radially exterior of the first said zone and that includes at least part of the zone of said blast of gaseous medium for retarding the rate of heat loss from said glass streams therein and means for controlling said second heat source independently of said first heat source, one of said heat sources and said blower defining therebetween an annular passageway open outwardly to the surrounding atmosphere for the flow of gases induced therethrough by said blower.

5. Apparatus for attenuating fine fibers from fiberizable material, said apparatus comprising, in combination, a rotary centrifuge the periphery thereof having a plurality of stream forming orifices therein, annular heat source positioned for applying heat onto the periphery of said centrifuge and into a first zone adjacent the periphery of said centrifuge, an annular blower having its blast emitting orifice radially spaced from said heat source and directed axially of said centrifuge, said heat source and said blower defining therebetween an annular passageway open outwardly to the surrounding atmosphere, said blower acting to apply tractive forces to fibers attenuated from said streams and to induce gases through said passageway into the space between the periphery of said centrifuge and said blower.

6. Apparatus for attenuating fine fibers from fiberizable material, said apparatus comprising, in combination, a rotary centrifuge the periphery thereof having a plurality of stream forming orifices therein, a first annular heat source positioned for applying heat onto the periphery of said centrifuge and into a first zone adjacent the periphery of said centrifuge, an annular blower having its blast emitting orifice radially spaced from said heat source and directed axially of said centrifuge, said heat source and said blower defining therebetween an annular passageway open outwardly to the surrounding atmosphere, said blower acting to apply tractive forces to fibers attenuated from said streams and to induce air through

said passageway into the space between the periphery of said centrifuge and said blower, and a second annular heat source radially spaced exteriorly of the first said heat source and positioned for heating the induced air prior to its entry into such space and thereby to reduce the density of such induced air.

7. Apparatus for attenuating fine fibers from fiberizable material, said apparatus comprising, in combination, a rotary centrifuge the periphery thereof having a plurality of stream forming orifices therein, an annular heat source positioned for applying heat onto the periphery of said centrifuge and into a first zone adjacent the periphery of said centrifuge, an annular blower having its blast emitting orifice radially spaced from said heat source and directed axially of said centrifuge, said heat source and said blower defining therebetween an annular passageway open outwardly to the surrounding atmosphere, said blower acting to apply tractive forces to fibers attenuated from said streams and to induce air through said passageway into the space between the periphery of said centrifuge and said blower, and control means for limiting the mass of air induced through said passageway for only partially satisfying the eductor requirements of said high velocity blast.

8. Apparatus for the continuous attenuation of fine fibers from heat softened glass comprising, in combination, a rotary centrifuge having a multiplicity of stream forming orifices in its periphery, means for supplying molten glass at attenuating temperature to said centrifuge, means for mounting and rotating said centrifuge on a vertical axis at such speed as to centrifugally project streams of molten glass outwardly through said orifices, an annular steam blower housing concentric with and radially spaced exteriorly of said centrifuge and defining with said centrifuge an annular space through which said streams are projected from said centrifuge, said blower having a blast orifice located above the level of projection of said streams and directed downwardly at the outer side of such space, the blast from said steam blower acting to apply tractive forces to fibers attenuated from said streams and to induce gases into such annular space by its eductor effect, an annular heater mounted concentrically with said centrifuge for applying heat to the peripheral portions of said centrifuge and to a zone circumjacent said centrifuge and comprising principally the inner part of such space, said blower and said heater defining therebetween an annular passageway open outwardly to the surrounding atmosphere for flow of such induced gases into such annular space, and annular means concentric with and radially spaced exteriorly of said centrifuge and said annular heater for controlling the density of such induced gases.

9. Apparatus for the continuous attenuation of fine fibers from heat softened glass comprising, in combination, a rotary centrifuge having a multiplicity of stream forming orifices in its periphery, means for supplying molten glass at attenuating temperature to said centrifuge, means for mounting and rotating said centrifuge on a vertical axis at such speed as to centrifugally project streams of molten glass outwardly through said orifices, an annular steam blower having a downwardly directed blast concentric with and radially spaced exteriorly of said centrifuge, said blast defining with said centrifuge an annular space through which said streams are projected from said centrifuge, the blast from said steam blower acting to apply tractive forces to fibers attenuated from said streams and to induce gases into such annular space by its eductor effect, an annular heater mounted concentrically with said centrifuge for applying heat to the peripheral portions of said centrifuge and to a zone comprising principally the inner part of such space, said steam blower and said heater defining therebetween an annular passageway open outwardly to the surrounding atmosphere for flow of such induced gases into such annular space, and a second annular heater concentric with

15

and radially spaced exteriorly of the first said annular heater for heating such induced gases prior to entry into such annular space and thereby to reduce the density of such induced gases.

10. Apparatus for the continuous attenuation of fine fibers from heat softened glass comprising, in combination, a rotary centrifuge having a multiplicity of stream forming orifices in its periphery, means for supplying molten glass at attenuating temperature to said centrifuge, means for mounting and rotating said centrifuge on a vertical axis at such speed as to centrifugally project streams of molten glass outwardly through said orifices, an annular steam blower having a downwardly directed blast concentric with and radially spaced exteriorly of said centrifuge, said blast defining with said centrifuge an annular space through which said streams are projected from said centrifuge, an annular heater mounted concentrically with said centrifuge and radially spaced interiorly of said steam blower for applying heat to the peripheral portions of said centrifuge and to a zone comprising principally the inner part of such space, the blast from said steam blower acting to apply tractive forces to fibers attenuated from said streams and to induce ambient gases into such annular space by its eductor effect, means mounted concentrically with said centrifuge and at the inner side of said annular heater for severely restricting the flow of ambient gases between said centrifuge and said annular heater into such annular space, and annular control means concentric with and radially spaced exteriorly of said centrifuge and said annular heater for controlling the flow of induced gases through the space between said annular heater and said steam blower.

11. Apparatus for the continuous attenuation of fine fibers from heat softened glass comprising, in combination, a rotary centrifuge having a multiplicity of stream forming orifices in its periphery, means for supplying molten glass at attenuating temperature to said centrifuge, means for mounting and rotating said centrifuge on a vertical axis at such speed as to centrifugally project streams of molten glass outwardly through said orifices, an annular steam blower housing concentric with and radially spaced exteriorly of said centrifuge and defining with said centrifuge an annular space through which said streams are projected from said centrifuge, said blower having a blast orifice located above the level of projection of said streams and directed downwardly at the outer side of such space along the inner face of said steam blower housing for attenuating said streams into fine fibers, means for substantially preventing the flow of ambient gases through the inner part of such space, the blast from said steam blower acting to induce ambient gases through the outer part of such annular space by its eductor effect, an annular heater mounted concentrically with said centrifuge for applying heat to the peripheral portions of said centrifuge and to a zone comprising principally the inner part of such space, said steam blower and said heater defining therebetween an annular passageway open outwardly to the surrounding atmosphere for flow of such induced gases into such annular space, and a second annular heater concentric with and radially spaced exteriorly of said centrifuge and of the first said annular heater for heating such induced gases prior to entry into such annular space.

12. Apparatus according to claim 11 in which the first annular heater is positioned in part above the peripheral portion of the centrifuge and above the inner

16

part of the annular space, the annular steam blower housing cooperates with the housing of one of said annular heaters to form an annular orifice for said induced gases leading into such annular space, and the second said annular heater is located for directing its heat across such annular orifice for preheating such induced gases to reduce the density thereof.

13. Apparatus for the continuous attenuation of fine fibers from heat softened glass comprising, in combination, a rotary centrifuge having a multiplicity of stream forming orifices in its periphery, means for supplying molten glass at attenuating temperature to said centrifuge and means for mounting and rotating said centrifuge on a vertical axis at such speed as to centrifugally project streams of molten glass outwardly through said orifices, an annular steam blower concentric with and radially spaced exteriorly of said centrifuge defining with said centrifuge an annular space through which said streams are projected from said centrifuge, an annular heater mounted concentrically with said centrifuge and radially interiorly of said blower for applying heat to the peripheral portions of said centrifuge and to a zone comprising principally the inner part of such space, said steam blower and said annular heater defining therebetween an annular passageway open outwardly to the surrounding atmosphere for flow of reduced gases into such annular space, said blower having a blast orifice located above the level of projection of said streams and directed downwardly at the outer side of such space for attenuating said streams into fine fibers, the blast from said steam blower acting to induce ambient gases into such annular space by its eductor effect, and means for substantially preventing the flow of ambient gases through the space between said centrifuge and the inner side of said annular heater.

14. Apparatus according to claim 13 and a second annular heater concentric with and radially spaced exteriorly of the first said annular heater for preheating such induced gases prior to their entry into the annular space to reduce the density thereof.

15. Apparatus according to claim 13 in which the face of the periphery of the centrifuge is generally cylindrical and in which the annular heater is a gas burner having a plurality of concentric circular rows of jet orifices leading from a common manifold, there being at least one row of orifices overlying the peripheral portions of the centrifuge and more than one row of orifices stepped down vertically and extending along radii progressively greater than the radius of the periphery of said centrifuge, the stepped down orifices being spaced vertically from each other distances totalling approximately the vertical dimension of the face of the periphery of said centrifuge whereby said face of said centrifuge is evenly heated.

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