April 13, 1971 E. T. STRICKLAND ET AL 3,574,581

BUSHING FOR USE IN EXTRUDING FIBERS

Filed Sept. 13, 1968 2 Sheets-Sheet 1

FIG. 1.

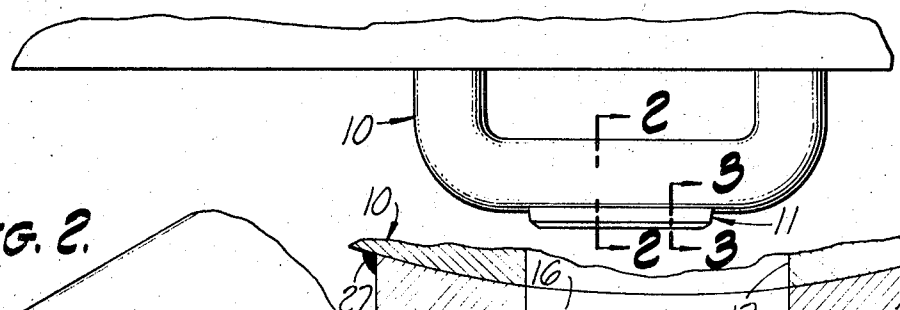
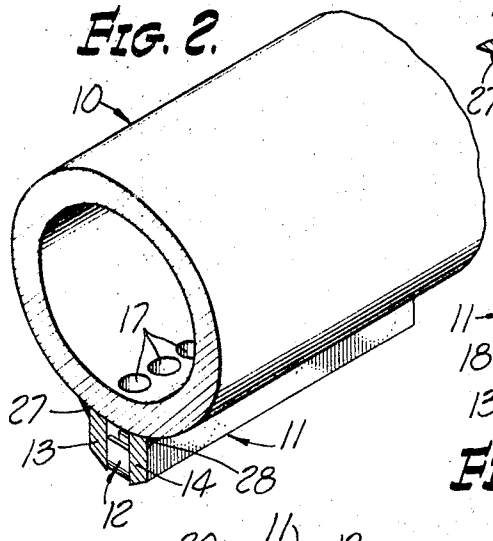


FIG. 2.



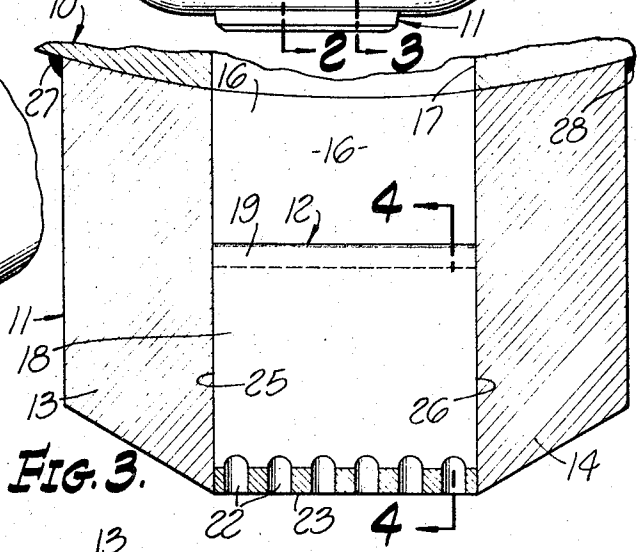


FIG. 3.

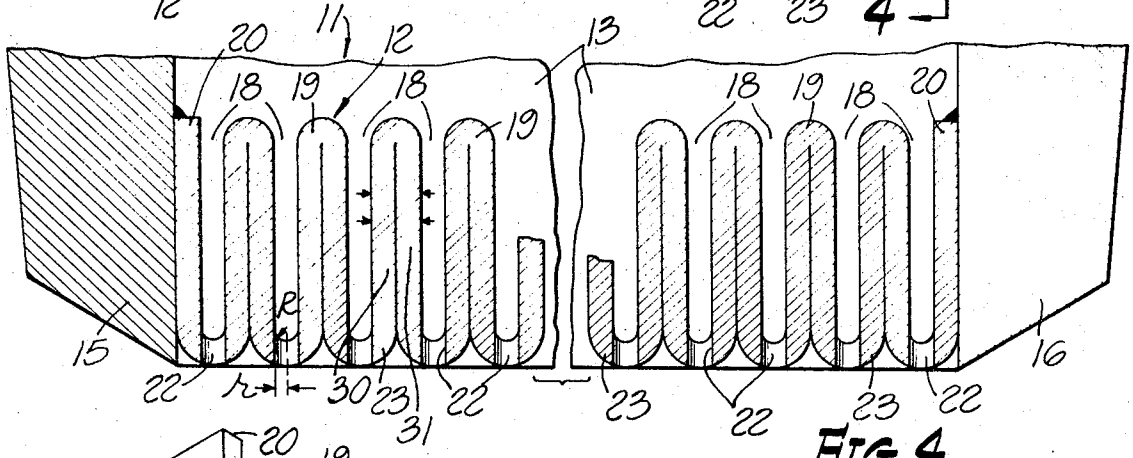


FIG. 4.

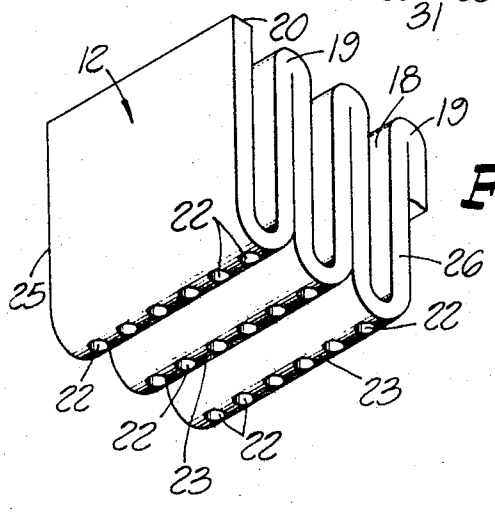


FIG. 5.

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BUSHING FOR USE IN EXTRUDING FIBERS

Filed Sept. 13, 1968 2 Sheets-Sheet 2

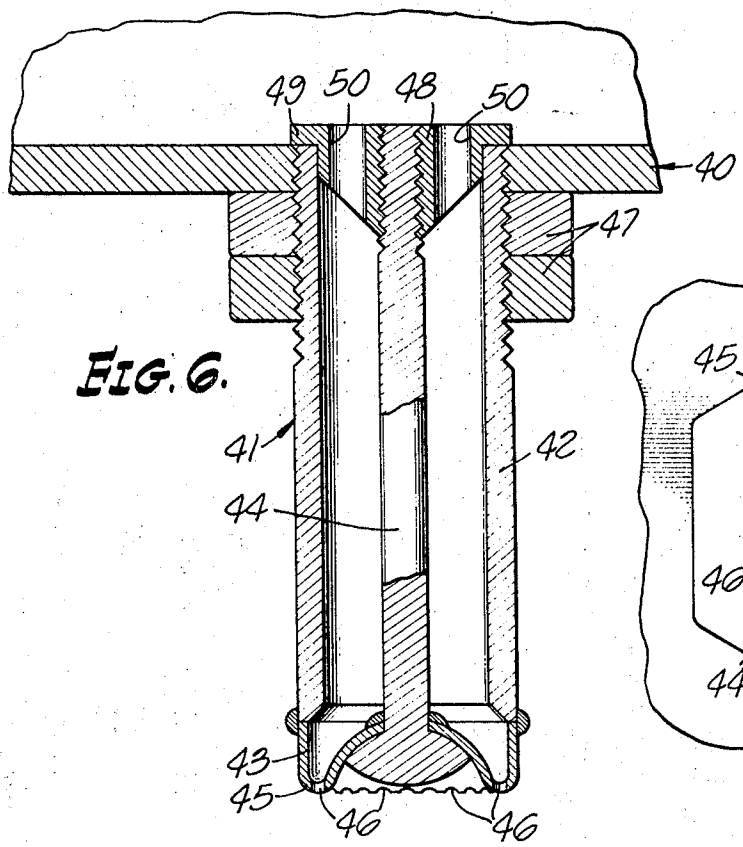


FIG. 6.

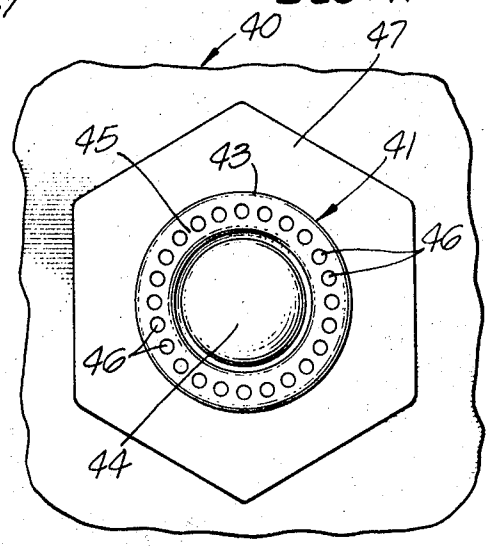


FIG. 7.

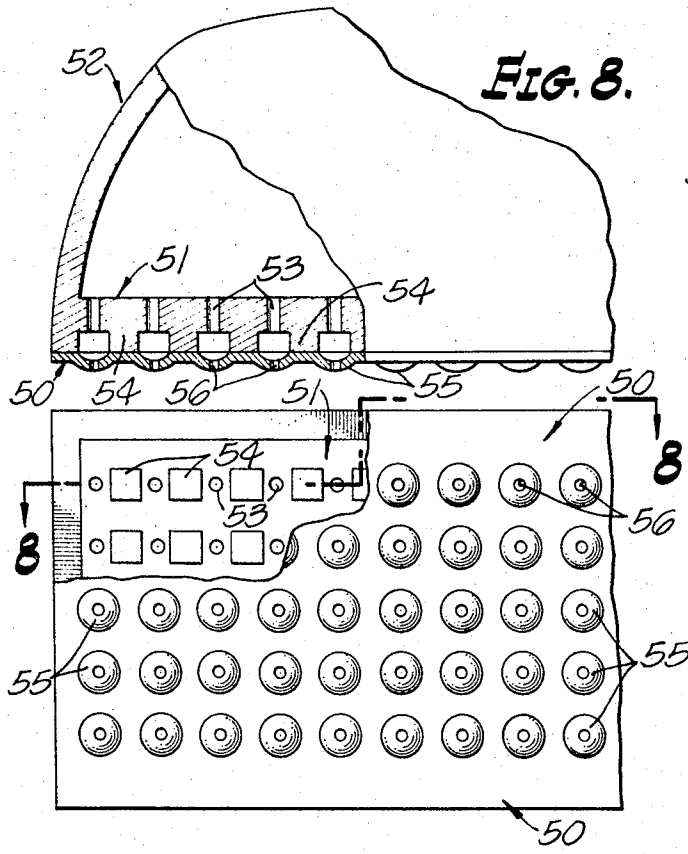


FIG. 8.

FIG. 9.

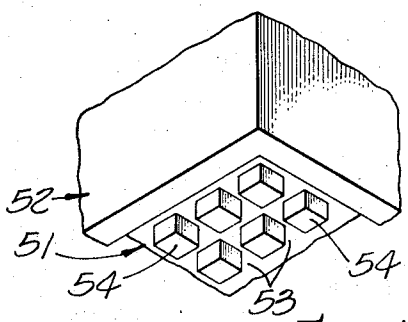


FIG. 10.

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3,574,581

BUSHING FOR USE IN EXTRUDING FIBERS

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Filed Sept. 13, 1968, Ser. No. 759,736
Int. Cl. C03b 37/02
U.S. Cl. 65—1 16 Claims

ABSTRACT OF THE DISCLOSURE

A bushing for use in extruding fibers under pressure from high temperature meltable material, such as molten glass. The bushing includes a plurality of tiny and closely spaced orifices through which the material is extruded. There are described herein various geometrical configurations for bushings which permit the use of a thin wall at the orifice area which can be subjected to high internal pressure with relatively low stress on the wall. The wall of the bushing at the orifice area preferably has a thickness less than several times the diameter of an orifice. One configuration is in the form of a folded or pleated ribbon of thin metal, the ribbon providing one or more apexes each having one or more orifices through which the material is extruded. Another configuration provides a circular wall in the form of a section of a toroid at the orifice area, and another provides plural dimple-like orifice areas substantially in the form of sections of spheres. For glass fiber extrusion, the bushing typically is made from a thin sheet of high temperature resistant material, such as platinum, platinum alloys, or other suitable metals or alloys.

The present invention is an improvement over applicants' copending application Ser. No. 556,800, filed May 13, 1966, entitled "Apparatus and Process for Extruding Fibers," now abandoned in favor of continuation application Ser. No. 3,558, filed Jan. 8, 1970, the disclosure of which is incorporated herein by reference.

This invention relates to bushings for use in extruding fibers, and more particularly to bushing configurations enabling thin wall orifice areas of low stress for extruding fibers under pressure from a high temperature meltable material, such as glass.

Fibers and filaments are produced from many substances, and in recent years there has been considerable activity in the production of filaments from glass to produce fiber glass. Fiber glass has many uses including insulation, yarn, glass reinforced plastic, and so forth. In the production of fiber glass, molten glass typically flows through nozzles or tips in a "bushing" resulting in fibers or filaments which then are cooled and drawn onto a winding reel or forming tube. The equipment for melting the glass, headers or manifolds for feeding the molten glass to the bushings, the bushings, and associated equipment are massive in size. Elaborate temperature control and insulation are utilized to maintain the bushings at a precise temperature. The bushings and headers are made from expansive materials, such as platinum, and represent a tremendous investment, in addition to the high cost of the other associated and control equipment. Repair and replacement of the bushings is difficult and time consuming.

As a result of the extreme coalescing characteristic of liquid glass, conventional fiber glass forming equipment utilizes bushings having large, complex, individually fabricated and widely spaced orifice nipples to obtain the necessary separation of the drawn fibers. Usually, each bushing provides one end of roving, that is, 204 fibers or filaments. Several filaments generally break during each run of one pound of glass, and when a filament breaks

a large drop of glass forms. If this drop touches other filaments, neighboring filaments likewise are broken in a rapidly widening ring. The orifices must be spaced widely enough to prevent this occurrence. When a one pound run is finished and the drawing process has ceased, the next run starts anew with a full complement of 204 filaments. This is accomplished by allowing a waiting period during which time a drop is formed at each nozzle by the oozing glass, and each drop must weld to the neighboring drops so that the filaments broken during the previous run will be caught and restarted. Accordingly, it is generally required that spacing between the orifices be more than the radius of a drop but less than the diameter of a drop.

It is well known that the viscosity of glass at and near fiber forming temperatures changes rapidly with slight changes in temperature. When flowing glass is cooled somewhere along its flow path, channeling of the flow results unless great care is exercised to maintain temperature uniformity. The highly unstable channeling characteristic of flowing glass causes serious flow rate variations. The hotter and lower viscosity glass begins to flow faster carrying more and more heat to its point of egress, while the cooler and slower flowing glass cools off more and becomes even slower in its flow rate. Such instability cycles are untenable in drawing glass fibers. A certain amount of flow rate instability is inherent in the bushing assembly designed in conventional filament drawing equipment. This instability results from irregularities in the shape of nipples which cause irregularities in loss of heat energy through radiation and convection and gain of heat energy through resistance heating. The surface areas of the bushing are so large that insulation is required wherever possible to prevent excessive total heat loss, and this in turn causes local temperature increases. However, the total orifice area cannot be insulated and is expose to the lower temperatures of the room in which the equipment is operating. Consequently, this area suffers considerably greater energy losses than elsewhere in the overall system. The higher glass temperature in the insulated area and the lower temperature of the glass in the orifice area results in localized temperature differences which in turn cause glass flow irregularities through the nozzles, as well as cause channeling which further aggravates the problem.

Accordingly, practical production facilities for producing fiber glass on such apparatus requires careful and precise temperature control. Great care is exercised through the use of multiple thermocouple temperature sensing probes controlling current regulators which in turn control the current to the bushings to provide an average temperature generally suitable for fiber forming. In spite of careful temperature control, the residual deficiency of the apparatus still results in a certain rate of fiber breakage. Additionally, glass is to a large extent pulled out of the orifice by the drawing tension of the present systems, and since this tension is markedly affected by small variations in the external environment, filament uniformity is adversely affected and breakage occurs.

Filament breakage is costly and time consuming. As a compromise, many fiber drawing facilities provide only short runs of filaments, but even then restarting after a run is time consuming and must be performed carefully. A typical run, called a "cake" consumes approximately a pound of glass, and a roving made from 30 cakes, for example, typically weighs approximately 30 pounds. Consequently, typical roving packages are small, 30 to 35 pounds, and the handling and transportation of such small packages for ultimate use, such as in laminating machines, is costly. Also, in order to maintain a continuous production without interruption, the tail roving of a spool being used is tied to the head of a new roving spool thereby causing a joining knot. If this knot sub-

sequently is drawn into a laminating machine, rejection of a finished part frequently occurs since the joining knot often protrudes through an otherwise smooth surface of the laminate. This results not only in a higher roving cost, but also in a higher lamination cost.

Furthermore, the labor investment in a conventional glass melting and bushing assembly is too great to tolerate any components other than those having the longest service life, thus requiring the use of expensive materials, such as platinum. The large complex platinum devices cost thousands of dollars per end. As a result of these costs, and the other costs involved, careful controls in the use of the expensive materials are provided as well as safeguards in their use, such as vaults. Because of the size and cost of conventional fiber drawing equipment, integrated production lines with both the fiber forming equipment and laminating equipment are impractical, and also conventional fiber equipment makes experimentation with new materials and new fiber drawing techniques almost prohibitively expensive.

In an exemplary embodiment in said copending application entitled "Apparatus and Process for Extruding Fibers," a high temperature meltable material such as glass is heated to a temperature at which it becomes liquid, and is forced into a bushing having a plurality of closely grouped simple and tiny passages or orifices thereby causing extrusion of the material as fibers or filaments through the orifices. A typical bushing is in the form of a simple tube. Glass may be heated in a furnace and pumped or otherwise forced into the bushing, or solid glass may be forced into a bushing which it at a temperature sufficient to melt the glass. The orifice area is curved with the lowest point hereof in the orifice area, such as arced in the direction of filament extrusion. A typical bushing according to said application may include two-hundred and four closely grouped orifices within an area of a small fraction of an inch for extruding two-hundred and four filaments to provide one end of a roving.

In some instances unusually high pressure, such as several hundred pounds per square inch, is required to separate the streams of glass being extruded through the closely spaced tiny and simple orifices in a bushing thereby placing high stresses on the bushing. There are only a few metals available today which can be used in air at the temperatures required for filamentizing glass, an example being platinum, and possibly molybdenum clad with a nickel-chromium alloy such as that sold under the tradename Inconel. Such materials are so near their melting point that even low stresses in these metals produce high amounts of creep. For example, it has been found that platinum, the preferred metal, will creep to destruction within one month when subjected to a sustained stress of eight hundred pounds per square inch.

Accordingly, it is a principal object of the present invention to provide an improved bushing for use in extruding fibers from a high temperature meltable material such as glass.

It is an additional object of this invention to provide a bushing having a configuration whereby the required high pressures for separating the liquid into discrete streams from a flooded bushing may be applied while still causing only low stress in the bushing material.

It is a further object of this invention to provide a bushing for use in forming fiber glass wherein the required high hydraulic pressures applied to the glass for extruding same into discrete streams results in only low stress in the bushing.

Another object of this invention is to provide a bushing having extended life for use in extruding fibers and which is capable of restraining fluid under high pressures at temperatures approaching the melting point of the bushing material.

Another object of this invention is to provide a bushing having extended life for use in extruding glass fibers and which is capable of restraining molten glass under high pressures at temperatures approaching the melting point of the bushing material.

A further object of this invention is to provide a metal bushing for use in extruding fibers under pressure and which requires a minimum amount of metal in its fabrication.

A still further object of this invention is to provide a bushing configuration enabling extruded glass to follow a relatively short path through an orifice therein by decreasing the pressure drop through the orifice from the inside to the outside of the bushing.

Another object of this invention is to provide a bushing having the smallest possible curvature, at an apex thereof through which an orifice is provided, as compared to the size of the orifice.

A further object of this invention is to provide a bushing for extruding glass wherein the dwell time of glass through an orifice therein is at a minimum to reduce the affect of temperature differentials through the orifice, and to reduce the adverse effect of partial vitrification which occurs if this dwell is greater than a few milliseconds. This effect—or lack of it—is known as a "second filament anomaly."

These and other objects and features of the present invention will become more apparent upon reference to the following description and drawings in which:

FIG. 1 is a simplified elevational view of a manifold having attached thereto a form of bushing according to the present invention;

FIG. 2 is a cross-sectional view of the manifold and bushing taken along a line **2—2** of FIG. 1;

FIG. 3 is a cross-sectional view taken along a line **3—3** of FIG. 1 and illustrates in cross-section one of the orifice areas of the bushing;

FIG. 4 is a cross-sectional view of the bushing taken along a line **4—4** of FIG. 3 and illustrates a side cross-sectional elevation of the bushing;

FIG. 5 is a partial perspective view illustrating the lower exterior portion of the bushing;

FIG. 6 is a cross-sectional elevational view of a circular bushing according to the present invention;

FIG. 7 is a bottom view of the bushing in FIG. 6;

FIG. 8 is a partial cross-sectional elevational view of another form of bushing according to the present invention;

FIG. 9 is a partial bottom view, partially in section, of the bushing in FIG. 8; and

FIG. 10 is a fragmentary perspective view of a portion of the supporting structure for the bushing.

According to the concepts of the present invention, a bushing is formed from a thin sheet of uniform thickness having one or more simple and tiny perforations respectively forming one or more orifices. When pressure is applied to force a material, such as glass, through an orifice, the sheet in effect becomes a diaphragm and the pressure produces tension in the diaphragm. It is desirable that the smallest possible radius of curvature at the orifice area be provided inasmuch as the tension is an inverse function of the radius of curvature of the diaphragm. One approach to reducing the stress in the sheet is to thicken it; however, this results in the orifice (which is a simple hole through the thickness of the sheet) being lengthened thereby increasing the viscous drag, reducing the flow of material and making it necessary to increase the pressure and, therefore, the resulting stress on the diaphragm. Thus, increasing the thickness of the sheet to the point where the length of the orifice is much greater than its diameter results in no gain in reduction of stress. The thickness of the sheet preferably is less than several times the diameter of an orifice.

Further, according to the concepts of the present invention, one form of bushing comprises a ribbon of sheet material which is folded or pleated to provide one or more apexes having one or more orifices therethrough. This construction is easy to fabricate and low in cost, and

provides a maximum reduction of stress while at the same time enables the orifice area to be compact, the latter being an important feature which is described in said above-noted application. Another form of bushing comprises a substantially circular sheet of material which is raised at its center and periphery to essentially provide a circular fold or arcuate section in the form of a segment of a toroid having orifices through the apex thereof. A further form of bushing according to the present invention is essentially in the form of a thin dimple sheet, the dimples substantially being segments of a sphere and having orifices therethrough. This latter form of bushing is reinforced by a waffle-like member affixed thereto.

Referring now to the drawings, FIG. 1 illustrates a manifold **10** in which a material, such as molten glass, is supplied under pressure in a liquid form, and a bushing **11** according to the present invention affixed thereto. As described in said above-noted application, the manifold **10** may be coupled with a furnace or the like which supplies molten glass into the manifold. Likewise, a pressure source, such as a viscosity pump, preferably is provided to apply suitable pressure to the liquid glass in the manifold, although in some instances the pressure head provided by the elevation of the liquid glass may be sufficient. A viscosity pump may be used in accordance with the teachings of applicants' copending application Ser. No. 613,562, filed Feb. 2, 1967, now patent No. 3,446,149 granted May 27, 1969 entitled "Pump," the disclosure of which is incorporated herein by reference.

Only one bushing **11** is shown affixed to the manifold **10**, it being noted that one or a plurality of bushings may be mounted on a single manifold or on plural manifolds. The exposed area of a bushing **11** having two hundred orifices, for example, may be approximately .60 inch long by .155 inch wide, or only .093 square inch.

The bushing **11** includes a "folded ribbon" **12**, slab sides **13** and **14**, and ends **15** and **16**. A typical thickness of the ribbon **12** is between approximately .005 inch and .015 inch. The sides and ends are relatively thick compared to the thickness of the ribbon. The ribbon **12** may be formed of a long thin sheet of material, for example, .010 inch thick platinum shim stock. The sides and ends may be formed of the same material and diffusion welded to the ribbon **12**, and the entire bushing welded around its upper periphery to the underside of the manifold **10**. The manifold **10** includes apertures **17** above the bushing to allow molten glass to be forced into passageways **18** between folds **19** and the ends **20** of the ribbon. A plurality of orifices **22** are formed through each of the apexes or orifice areas **23** of the ribbon **12**. The inside radius (R) of curvature (note FIG. 4) at the apexes **23** should not exceed several times the orifice diameter and preferably is the same as the radius (r) of an orifice to provide optimum stress reduction in the bushing. The ribbon, sides, ends and orifices are illustrated approximately to scale in FIGS. 3 through 5.

An enlarged cross-sectional view of the bushing taken transverse to the ribbon **12** is shown in FIG. 3. The slab sides **13** and **14** are diffusion welded to side edges **25** and **26** of the folded ribbon **12** as noted previously. The slabs in turn are welded at **27** and **28** to the manifold **10**. The ends **15** and **16** also are similarly welded to the manifold **10** thereby firmly securing and sealing the bushing to the manifold The folds **19** in the ribbon can be made as deep as desired (note FIG. 4), and thus the edge areas (note edge area **26** in FIG. 5) of the ribbon **12** are relatively large. Inasmuch as there is a large edge and thus large weld area, the stress per unit area at the weld is low. This same large area supports the hydraulic force applied to the grid formed by the folded ribbon. The total lengthwise cross-section (note FIG. 4) of the folded ribbon is placed in double shear, and inasmuch as this cross-sectional area is very large, the shear stress per unit area is extremely low. This stress can be easily reduced to less than the glass pressure.

One of the principal features of the ribbon configuration is its effective lack of straight walls found in some prior bushings which are particularly susceptible to deformation or rupture under the high temperatures and pressures involved in extruding glass fibers. The pressures within the passageways **18** act in equal and opposite directions upon the sections of folded ribbon. That is, for example, the pressure within the third and fourth passageways **18** (counting from the left in FIG. 4) act equally and oppositely on the ribbon sections **30** and **31** as indicated by the arrows in these passageways. This effectively results in only a section of a tube or cylinder at the lower end, or orifice area, of the bushing being subjected to outward deformation forces, and this area having the aforementioned radius of curvature is particularly capable of withstanding such pressures. Thus, the straight sides (e.g., **30** and **31**) of the ribbon mutually reinforce each other. Bulky ends **15** and **16** are used to reinforce the ends **20** of the ribbon.

An exemplary ribbon may be .010 inch thick platinum shim stock having orifices of .010 inch diameter

$$(r=.005)$$

A "one end" (two hundred orifices) bushing may be formed with twenty apexes **23** each having ten orifices **22** (only six orifices **22** are shown in FIG. 3 for simplicity of illustration) on .015 inch centers. In this case the exposed bushing area (neglecting the sides and ends, note FIG. 5) is .60 inch long by .155 inch wide or only .093 square inch. The glass extrusion rates may be several inches per second, and with orifice diameters of .010 inch the rate may be, for example, approximately four inches per second.

When compared to the typical bushings used for conventional glass extrusion, a bushing according to the present invention is extremely small and in this respect is in accordance with the basic concepts described in said above-noted application, entitled "Apparatus and Process for Extruding Fibers." Additionally, the amount of bushing material, such as a precious metal like platinum, used in typical state-of-the-art bushings is thousands of times greater than a bushing according to the present invention having an equal number of orifices.

The manifold **10** may be supplied with molten glass as discussed above. Alternatively, the manifold **10** may be an uninsulated resistance heated tube (electrical current is supplied through the manifold) to melt a rod or rods of glass fed into the ends thereof as described in said last noted application. Additionally, an exterior coaxial tube may be applied over the manifold and bushing and open throughout the orifice area as described in said last mentioned application to supply an inert gas therebetween to prevent oxidation of the bushing.

FIGS. 6 and 7 illustrate another form of a bushing according to the concepts of the present invention. A manifold **40**, similar to the manifold **10**, has secured thereto a bushing assembly **41** including a depending cylindrical feeder **42** having secured thereto an orifice sheet or plate **43**. The orifice plate **43** is substantially circular having its periphery welded to the lower edge of the feeder **42**, and being supported by a central rod **44** welded at a central aperture in the plate **43**. The plate **43** is folded in the manner shown in FIG. 6 to provide a circular and arcuate orifice area **45** in the form of a section of a toroid, and has tiny closely spaced orifices **46** therethrough.

The feeder **42** may be threaded into the bottom of the manifold **40** and secured thereto by a nut or nuts **47**. The central rod **44** may have its upper end threaded into a mounting member **48** having a shoulder **49** for supporting the same, and apertures **50** therethrough for passing the material to be extruded. The orifice plate **43** is relatively small and thin as is the case with the ribbon bushing and may have, for example, a diameter of

twenty-one thirty-seconds of an inch at the center line of the orifices **46**. All of the components of the bushing assembly **41** may be made of a high temperature meltable material such as platinum, platinum alloys, and similar metals. The other embodiments shown and described herein also may be formed of such metals or equivalents thereof, the only requirement being that the thickness of metal used withstand the pressures involved at high temperatures.

Another form of bushing is illustrated in FIGS. 8 and 9 and comprises a thin dimpled sheet **50** affixed to a base such as a "waffle plate" **51**. The plate **51** may be a separate member or form the bottom of a manifold **52** which preferably has an arcuate top to form a suitable pressure vessel for the molten glass. The waffle plate **51** has a plurality of passageways **53** for molten glass. The bottom of the plate **51** has a plurality of depending fingers **54** much the same in general configuration as those found on a conventional waffle iron. The orifice plate **50** is diffusion welded around the lower periphery of the waffle plate **51** and to the depending fingers **54** thereof.

The orifice plate **50** has a plurality of "dimples" **55** substantially in the shape of sections of spheres. Tiny orifices **56** are provided through the respective dimples **55**. Inasmuch as suitable materials, such as platinum, creep at high temperatures and high pressures, the small and closely spaced small diameter dimples **55** enable a bushing to be provided wherein the stresses therein are low. Reinforcement is provided by the waffle configuration of the plate **51**; and by making the dimples as small as possible, deformation stresses are kept at a minimum. Although single orifices **56** are shown through each dimple **55** for simplicity of illustration, each preferably contains at least a cluster of several orifices. Preferably, approximately seven to fifty tiny orifices are provided in each dimple in a cluster or in one or more circles. Typically seven or nineteen may be provided in a cluster, and if more are provided they are arranged in one or more circles.

Consonant with the objectives set forth earlier, it is preferred that the sheet **50** have a thickness of only a few thousandths of an inch to minimize the length of the orifice through which the material being extruded flows. The waffle plate **51** may be relatively thick for structural reasons, and may be milled with the waffle-like pattern and drilled to provide the passageways **53**. Because of the high temperatures involved, many materials cannot stand the pressures required for extruding glass, and the closely spaced waffle-like fingers or appendages therefore give the required support to the thin metal sheet **50**. The fingers **54** are rod like supports, and may be square, round, rectangular, triangular, and so forth. Alternatively, the waffle plate **51** may be a solid plate without the fingers **54**, but with larger holes **53** (e.g., one-eighth inch diameter) feeding the dimples **55**. The sheet **50** is then welded to the plate **51** intermediate the holes **53** to provide a sufficiently reinforced bushing.

Although the embodiment illustrated in FIGS. 8 and 9 is shown as being rectangular, it can be constructed in other configurations, and preferably may be round wherein the upper portion of the manifold **52** then can be hemispherical to provide the best high pressure resistant chamber. As with the other embodiments described herein, electrical current may be caused to flow through the waffle-like structure to maintain the desired attenuating temperature for glass.

The present embodiments of this invention are to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims therefore are intended to be embraced therein.

What is claimed is:

1. Apparatus for extruding glass fibers from molten glass comprising

manifold means for containing a supply of molten glass and for supplying molten glass under sufficient pressure to bushing means to cause glass to egress through orifices in said bushing means and form fibers,

bushing means communicating with said manifold means for receiving molten glass from said manifold means and forming said fibers, said bushing means including thin folded ribbon means having successive layers of open and closed sections, the open section forming passageways for receiving said molten glass and having arcuate bottoms with orifices therein for forming said fibers, and said closed sections forming reinforcing walls between said open sections for allowing said ribbon means to be subjected to the high pressures required for obtaining and maintaining extrusion and separation of said fibers, and

supporting means affixed to said bushing means for supporting and affixing the bushing means to said manifold means and for providing enclosed passageways in said open sections of said ribbon means.

2. Apparatus as in claim **1** wherein the arcuate bottoms of said open sections of said ribbon means have an inside radius of curvature not exceeding several times the nominal diameter of an orifice therethrough.

3. Apparatus as in claim **2** wherein the orifices through the bottoms of the open sections of said ribbon means comprise a plurality of closely spaced short length orifices.

4. Apparatus as in claim **1** wherein said supporting means comprises side members affixed to the respective side edges of said ribbon means, and end members affixed to the respective ends of said ribbon means, said side and end members being affixed to said manifold means.

5. Apparatus as in claim **2** wherein said radius of curvature is approximately the same as the radius of an orifice.

6. Apparatus as in claim **1** wherein said ribbon means is formed of platinum or a platinum alloy and the inside radius of curvature is less than several times the diameter of an orifice.

7. Apparatus for extruding glass fibers from molten glass comprising

manifold means for containing a supply of molten glass and for supplying said molten glass under sufficient pressure to bushing means to cause molten glass to egress through orifices in said bushing means and form fibers, said manifold means including a member having an opening therein,

bushing means communicating with said opening in said manifold means for receiving molten glass therefrom for forming said fibers, said bushing means comprising a thin metal sheet in the form of a pleated ribbon having successive walls forming open and closed sections, each open section forming a passageway communicating with said manifold for receiving molten glass therefrom and having at least an orifice through the bottom thereof, and each closed section forming substantially adjacent walls for providing a barrier between adjacent open sections for supporting the molten glass under the pressure required for fiber extrusion and separation, and

supporting means affixed to said bushing means for supporting and affixing the bushing means to said manifold means and for enclosing the sides of said open sections of said ribbon.

8. Apparatus for extruding glass fibers from molten glass comprising

manifold means for containing a supply of molten glass and for supplying said molten glass under sufficient pressure to bushing means to cause molten glass to egress through orifices in said bushing means and form fibers,

bushing means communicating with said manifold means for receiving molten glass therefrom for form-

ing said fibers, said bushing means comprising a thin metal sheet in the form of a pleated ribbon having successive walls forming open and closed sections, each open section forming a passageway communicating with said manifold for receiving molten glass therefrom and having a plurality of small closely spaced orifices through the bottom thereof, and each closed section forming adjacent walls for providing a structural barrier between adjacent open sections for supporting the molten glass under the pressure required for fiber extrusion and separation, and

supporting means affixed to the sides and ends of said ribbon for supporting and affixing the same to said manifold means and for enclosing the sides of said open sections of said ribbon.

9. Apparatus for extruding fibers from a high temperature meltable material comprising

manifold means for containing a supply of said material and for supplying molten material under sufficient pressure to bushing means to cause said material to egress through orifices in said bushing means and form fibers,

bushing means communicating with said manifold means for receiving molten material from said manifold means and forming said fibers, said bushing means including thin folded ribbon means having successive layers of open and closed sections, the open sections forming passageways for receiving said molten material and having arcuate bottoms with orifices therein for forming said fibers, and said closed sections forming reinforcing walls for said open sections for allowing said ribbon means to be subjected to the high pressures required for obtaining and maintaining extrusion of said fibers, and

supporting means affixed to said bushing means for supporting and attaching the bushing means to said manifold means and for providing enclosed passageways in said open sections of said ribbon means.

10. Apparatus for extruding glass fibers from molten glass comprising

manifold means for containing a supply of molten glass for supplying molten glass under sufficient pressure to bushing means to cause glass to egress through orifices in said bushing means for forming fibers, said manifold means including a member having at least an aperture therein,

bushing means communicating with said aperture in said manifold means for receiving molten glass and forming said fibers, said bushing means comprising an enclosure member having a passageway therethrough and a first end communicating with said aperture in said manifold means and a second end, a sheet affixed at said second end of said enclosure member and being raised at the periphery and center of the sheet to form an arcuate section in the form of a section of a toroid, said sheet having a plurality of tiny closely spaced orifices through the apex of said arcuate section, and the raised periphery of said sheet being affixed to said second end of said enclosure member and a central support member secured substantially at the center of said sheet for rigidly supporting said sheet and maintaining the arcuate form thereof under the molten glass pressure required for obtaining extrusion and separation of said fibers.

11. Apparatus as in claim **10** wherein said sheet is of thin metal.

12. Apparatus as in claim **11** wherein said sheet is of platinum.

13. Apparatus as in claim **10** wherein said arcuate section has an inside radius of curvature not exceeding several times the nominal diameter of an orifice therethrough.

14. In an apparatus for extruding fibers from a meltable material wherein means are provided for supplying said meltable material to bushing means in a fluid state under sufficient pressure to cause extrusion and separation of fibers egressing from orifices in said bushing means, said buhing means comprising

sheet means having a raised periphery and center to form an arcuate section in the form of a section of a toroid, said sheet means having a plurality of tiny closely spaced orifices through the apex of said arcuate section, and

enclosure means having one end secured to the periphery of said sheet means, and having a central member secured at the center of said sheet means, said enclosure means and central member rigidly supporting said sheet means for maintaining the arcuate form thereof under the fluid material pressure required for obtaining extrusion and separation of fibers, and said enclosure means providing a passageway for said fluid material to said orifices.

15. Apparatus for extruding glass fibers from molten glass comprising

manifold means for containing a supply of molten glass for supplying molten glass under sufficient pressure to bushing means to cause glass to egress through orifices in said bushing means for forming fibers, said manifold means including a member having at least an aperture therein,

bushing means communicating with said aperture in said manifold means for receiving molten glass and forming said fibers, said bushing means including a sheet of thin material having a plurality of dimple-like depressions therein substantially in the form of arcuate segments, said depressions being relatively closely spaced and each having a tiny orifice therethrough which said fibers are extruded, and said bushing means including supporting means for said sheet coupled with said manifold means, said support means including an enclosure for receiving molten glass from said manifold means and a support member having a plurality of openings and a plurality of depending fingers, said openings providing passageways for said glass and said fingers being secured to said sheet intermediate said depressions for supporting said sheet.

16. Apparatus as in claim **15** wherein said sheet is of thin metal.

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