

PATENT SPECIFICATION

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(54) METHOD AND APPARATUS FOR MANUFACTURING GLASS FIBERS

(71) We, KAISER GLASS FIBER CORPORATION, a Corporation organised and existing under the laws of the State of Nevada, U.S.A., of 300 Lakeside Drive, Oakland, California 94666, United States of America, and NITTO BOSEKI CO. LTD., a Company organised under the laws of Japan, of 1, Aza Higashi, Gonome, Fukushima-shi, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

In recent years, there has been considerable interest in the production of glass fibres. Due to the tremendous usages of glass fibres, this interest has been particularly focused on increasing the production of individual fibre drawing stations. In the production of fibres, molten glass is typically passed through nozzles or orifices in a bushing to create individual fibres. In addition to the problem of increased production, the apparatus used in such processes is typically quite expensive as it often times involves the use of inordinate amounts of platinum, complex orifices, high pressure generating equipment, and pressure resistant bushings.

It is one object of this invention to provide an improved method and apparatus for producing fibres from a high temperature molten material.

In accordance with one aspect of this invention, broadly stated, there is provided a method of forming glass fibres which comprises maintaining heat-softened glass at a perforated area of a metallic plate formed with orifices which open to and terminate at the outer face of the plate, extruding separate streams of molten glass through the orifices in the orifice plate, drawing glass fibres from the streams of heat-softened glass formed at each orifice, and directing a flow of gas into contact with the outer face of the orifice plate so as to maintain said outer face at a temperature below the temperature of the heat-softened

glass at said perforated area and to maintain the streams of glass associated with the individual orifices as separate streams.

More specifically, the invention provides a method of forming glass fibres which comprises:

(a) passing separate streams of molten glass through a plate having at least four rows of closely spaced orifices extending therethrough, the orifices opening to and terminating at the outer face of the plate and being spaced in flooding relationship;

(b) drawing fibres from cones of molten glass formed at each said orifice;

(c) directing a flow of rapidly moving gas upwardly to the orifice area in said plate, said flow being a generally single gas column at the cone and orifice area in an amount velocity and angle sufficient;

(i) to cool said cones to provide a stable cone formation and to maintain separation of cones thus preventing flooding;

(ii) to impinge on said plate essentially to eliminate stagnant gas adjacent said plate and to cause gas to move outwardly along said plate in all directions from said orifice area, and

(iii) to supply a source of gas to be sucked downwardly by the fibres; and

(d) heating the orifice plate by means of heating means associated therewith.

In accordance with another aspect of this invention, broadly stated, there is provided an apparatus for manufacturing glass fibres, comprising a container for molten glass, an orifice plate disposed at the base of the container and formed with orifices which open to and terminate at the outer face of the plate, means for drawing glass fibres from streams of molten glass passing through the orifices in the orifice plate, and means for directing a flow of gas onto the external surface of the orifice area of the orifice plate at such a velocity and such a volume that the outer face of the orifice plate is cooled to a temperature below the temperature of the molten

glass at the inlet end of the orifices and the streams of molten glass associated with the individual orifices are maintained as separate streams.

5 More specifically, the invention provides an apparatus for manufacturing glass fibres comprising:

(a) means for containing a head of molten glass;

10 (b) a plate constructed of a heat resistant material and disposed at the base of said containing means, said plate having at least four rows of closely spaced orifices extending therethrough, the orifices opening to and terminating at the outer face of the plate and being spaced in flooding relationship;

15 (c) heating means associated with the orifice plate for heating said orifice plate;

20 (d) means for withdrawing fibres from the orifices in the plate and

(e) means disposed below said plate and being in communication with a gas supply for directing a bulk flow of rapidly moving gas upwardly towards said orifices as a generally single gas column at the cone and orifice area in an amount, velocity and angle sufficient:

25 (i) to cool molten glass cones formed below the orifices during withdrawal of fibres therefrom to provide a stable cone formation and to maintain separation of cones thus preventing flooding;

30 (ii) to impinge on said plate essentially to eliminate stagnant gas adjacent said plate and to cause gas to move outwardly along said plate in all directions from said orifice area, and

35 (iii) to supply a source of gas to be sucked downwardly by the fibres.

Other aspects of this invention are described below.

40 The advantages to be achieved from the present invention are manifold. The orifice plate or bushing is simple to manufacture and employs less extremely expensive metal alloy than commercial bushings in use today. Compared to conventional practice employing orifices with tips, the radiant heat given off by the bushing employed in this invention is less and therefore the operator is subjected to less exposure to radiant heat. Inasmuch as there is less radiation, the present invention affords the possibility of employing less electrical energy. The above is particularly dramatic when comparing bushings of equal throughput.

55 Since high orifice densities may be realized, the present invention provides increased producing per unit area of orifice plate. Moreover, there is more throughput per orifice than is realized in conventional practice employing tips, because of a skin effect pumping action due to the cones being cooled by air, the shorter orifice length and the higher exit temperature from the orifice. The fibers have good uniformity and do not require

complex manufacturing apparatus. This invention does not require the use and complexity of fins, hood enclosures, expensive, non atmospheric gas mixed with carbon plating gases to create a non-wettable carbon barrier, arcuate pressure bushings, high pressure systems and does not require non-wettable alloys. In addition, it utilizes the simplest of cooling means.

This invention also provides considerable flexibility with regard to the number of fibers to be drawn from a bushing. The number of fibers required for final product application readily may be drawn from a single orifice area. Final products may require bushings producing strands having 1600, 2000, 3200, 4000, 20,000, or more fibers. The present invention has the potential of eliminating roving operations.

This invention further provides more flexibility in choosing windup speeds because commercially acceptable production rates (lbs. of glass) may be achieved employing more orifices and lower windup speeds which tend to reduce the risk of fiber breakage. Even at higher windup speeds, it has been found that "snap-out", wherein a large multitude of fibers break at essentially the same time, does not occur. Since the orifice plate is overwhelmed with high velocity upwardly moving gas, which moves outwardly along the orifice plate, no adjacent ambient gas (which may carry impurities that contaminate the fibers and cause fiber breaking) is drawn around the cones so that the environment around the cones is cleaner.

With a relative high density of fibers passing over the dressing fluid (binder) applicator roll, there is less loss, and therefore less consumption, of dressing fluid than experienced in conventional commercial processes. Inter-fiber scrubbing action appears to prevent excess pick up of dressing fluid by individual fibers so that later sling off of dressing fluid by the fibers is materially reduced. Reduced sling off of dressing fluid will result in a reduction of sizing in the air and both equipment and the work area will stay cleaner, thereby affording a better environment for the operator. Rapid quench of the glass also will reduce the content of glass volatiles in the surrounding environment, and the cooling gas which moves laterally outwardly from the bushing readily can be removed from the operating area to keep the operating area cooler.

Finally, this invention provides high quality glass fibers. Rapid glass quench (order of magnitude 100:1 compared to conventional type bushings), with a reduced loss of volatiles from the glass, results in a fiber more nearly corresponding to the composition of the glass in the molten bath. Moreover, the substantially greater cooling of the glass in the cones by conduction and convection, rather than cooling

aratus. This use is expensive, a carbon plat-
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 shings, which require non-
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 tion of the glass
 the substantially
 in the cones by
 ner than cooling 130

by radiation, provides a more tempered glass fiber.

This invention readily may utilize conven-
 tional glass furnaces, and conventional aux-
 iliary equipment, such as bushing heaters,
 dressing fluid applicators and windup equip-
 ment. Existing glass fiber operations may be
 converted for the practice of this invention by
 modification of the bushing and provision of
 proper cooling gas means.

This invention easily may be practiced with
 the head of glass normally maintained in a
 conventional glass furnace, which generally is
 from about 8 to about 14 inches (20cms to
 36cms) of molten glass. Indeed, the present
 invention can be practiced with a glass head
 of only about 1 inch (2.5cms) or less. Although
 pressures in excess of those provided by a
 head of glass require expensive equipment
 that may be difficult to maintain, such
 pressures may be employed if desired. The
 temperature of the molten glass in the bath
 obviously will depend upon the type of glass
 being used. With type E glass, the tempera-
 ture will be 2100°F to 2400°F (1150—
 1315°C). The choice of the temperature for
 the molten glass bath in the glass furnace for
 any type of glass is routinely established in
 conventional practice and is easily within the
 skill of the art.

The orifice plate used in this invention may
 be made of any alloy acceptable for operation
 under glass fiber forming conditions. The
 alloy may be wettable or non-wettable. A
 standard platinum alloy of 80% platinum and
 20% rhodium, or an alloy of 90% platinum
 and 10% rhodium, readily may be employed.
 Zirconia grain stabilized platinum alloys
 which have creep resistance may also be
 employed.

It will be understood that the word "plate"
 is used herein to denote a plate which is
 generally substantially flat, although it is
 intended to include plates which have small
 dimples or are in the form of gentle concave
 and/or convex configurations and which may
 be used without adversely affecting the prac-
 tice of this invention. Heat warpage of a flat
 orifice plate may result in convex and/or
 concave areas within the plate but such dis-
 tortions can readily be tolerated. Also, the
 orifice plate may be reinforced with ribs or a
 honeycomb structure on the molten glass side
 of the bushing.

With commercial tips, the gas (e.g., air)
 cools the tips substantially below the bulk
 temperature of the bushing. As the tips cool,
 the glass flowing through the tips is also
 cooled and becomes more viscous and flows
 less readily so that the tips act as a thermal
 valve which decreases glass throughput. In
 the practice of this invention, the metal tem-
 perature adjacent the orifice during operation
 should not become substantially less than the
 bulk temperature of the orifice plate so that

significant adverse thermal valve effects are
 avoided.

The thickness chosen for an orifice plate
 will be a function of bushing size, alloy
 strength, orifice size, orifice density, and the
 like. Generally the orifice plate need not be
 greater than 0.06 inches (1.52mm) thick and
 orifice plates 0.04 inches (1mm) thick have
 been successfully employed. The area in the
 bushing occupied by orifices readily may have
 a minimum dimension of at least 1/2 inch
 (1.27cm) with minimum dimensions of at least
 1 inch (2.5cms) being quite feasible. It is
 possible for the area in the bushing occupied
 by orifices to have dimensions of 10 inches ×
 10 inches (25.4cms × 25.4cms).

In accordance with the conventional prac-
 tice, the orifice plate or bushing is provided
 with heating means. Generally heating is
 accomplished by electrical resistance means.

The orifices in the orifice plate will
 generally be less than about 0.1 inch (2.5mm)
 in diameter and may be as small as about
 0.020 inches (0.5mm) in diameter. The
 arrangement of holes is a matter of choice and
 orifices may be arranged in a square, hexa-
 gonal or any other desired arrangement. In
 order to obtain maximum utilization of bush-
 ing area the orifices generally will be spaced
 not more than about 2 diameters, center-to-
 center, with spacings of from about 1.25 to
 about 1.7 diameters, center-to-center, being
 preferred. With smaller orifices, the metal
 between adjacent orifices may be as little as
 0.001 inch (0.025mm). It is apparent that the
 orifice spacing will depend in part on the
 thickness of the orifice plate alloy. If desired,
 periodic spaces having no orifices can be
 provided to add strength to the bushing. Care
 should be exercised, however, to avoid uneven
 air flow in the event such spacings are
 employed.

The orifice plates used in the practice of the
 present invention have at least 4 rows of
 orifices, preferably at least 10 to 11 rows of
 orifices, and most desirably at least 15 rows
 of orifices are provided with each row-con-
 taining at least 15 orifices. This invention
 permits the orifices to be spaced closely
 together with orifices in each row being
 spaced from orifices in its row and in
 adjacent rows in flooding relationship
 which, of course, is diametrically opposed
 to present practice. An orifice plate
 which would normally flood and would not
 maintain cone separation for practical produc-
 tion at operating glass pressure and tempera-
 tures can readily be employed in this inven-
 tion since the bulk gas movement establishes
 and maintains cone separation. Even though
 an orifice plate may flood and foreclose sus-
 tained production under normal operating
 conditions of glass pressure and glass tempera-
 ture just over the plate, such plate can be
 employed adopting the practice of this inven-

tion. In production, at least 90% production efficiency is generally desirable. Such rates and more can readily be attained by this invention.

5 Generally, for practical production, orifice density will be at least 50 orifices per square inch (6.45cm^2), (1 orifice per 12.9mm^2), preferably at least 100 orifices per square inch (6.45cm^2) (1 orifice per 6.45mm^2), and most desirably at least 200 holes per square inch (6.45cm^2) (1 orifice per 3.23mm^2) of the orifice area in the bushing. With very small orifices, the densities may range from 500 to 1000 orifices per square inch (6.45cm^2) (1 orifice per 1.29 to 0.65mm^2). Although orifice densities are given in orifices per square in. (6.45cm^2), it should be understood that the area occupied by the orifices may be less than 1 square inch (6.45cm^2).

20 Air is particularly preferred for this invention and can be at ambient temperature, or can be heated or cooled. Steam, finely dispersed water, other liquid droplets or the like can be added in the air if desired to increase its cooling capacity. Other gases such as, for example, nitrogen, carbon dioxide may be employed in combination with air or instead of air. A non-reducing gas or gaseous fluid, i.e., one that does not provide a reducing atmosphere at the cones and orifices plate is generally preferred. While a reducing gas is not preferred, such gas (e.g. methane, ethane, or the like) may be employed if desired. Since the gas is employed for cooling purposes it is preferred to employ gases of temperatures of about ambient temperature or less (e.g., 100°F (38°C) or less). It should be understood, however, that the benefits of this invention can also be achieved by warmer gas which may be, for example, even at 500°F (260°C), providing the volume of air is increased accordingly.

For ease of presentation description herein is couched in terms of air. It is to be understood, however, that the description is equally applicable to other gases.

45 In one method of start-up of the method of this invention, albeit one having a slower start-up, the orifice plate temperature which is about 1000°C from the previous shutdown is elevated to about the range of devitrification temperature, between about 1083°C and 1105°C for E type glass. This will also cause a thin layer of glass inside and above the orifice plate to be raised to this temperature. The mass of glass inside the bushing which has been maintained at a temperature of 1150°C to 1315°C is not affected. When the small quantity of glass adjacent the plate passes through the orifices, it will pass there-through as separated streams without wetting and without flooding the plate even though the plate may be constructed of a wettable alloy. While the resulting fibers are brittle, if handled carefully and slowly withdrawn,

while increasing the plate temperature well above the devitrification range and while simultaneously adjusting the air cooling, the small amount of devitrified glass can be quickly and completely rinsed out, at which time the glass can be handled in the standard fashion.

In somewhat different operation to speed startup, the temperature of the glass adjacent the plate is increased by increasing the temperature of the orifice plate itself so that the glass therefrom becomes less viscous and under the pressure of the head of molten glass within the bushing quickly begins to pass through the orifices in the bushing or orifice plate. Due to the wetting properties of the glass and the close proximity of orifices, the underside of the plate begins to flood. As soon as the volume of flooded glass is heavy enough to furnish the initial attenuating force, it is necessary to reduce the flow of the glass through the orifices, otherwise, separation cannot occur. In one preferred embodiment of this invention, this flow rate regulation is accomplished through temperature control of the orifice plate. In yet another preferred embodiment, the current flow to the plate can be kept constant, and the glass flow through the plate reduced to allow separation to occur by directing a steady flow of air to the plate thereby reducing the plate temperature. Once separation is achieved, this air flow can be reduced to allow the plate to heat up and function as described above.

As the glass drops flow through the orifices and flood the underside of the orifice plate, it will speed separation to reduce the temperature of the orifice plate into or at the edge of the glass devitrification temperature whereby the orifice plate functions as a molten glass thermic flow valve. This temperature reduction of 50°C to 150°C virtually stops the flow of glass through the orifice and allows for the flooding glass to flow or be drawn (e.g., with a glass rod) from the underside of the plates into individual glass fibers.

The early withdrawal rate should proceed generally at about $1/2$ inch (1.27cms) per second to avoid glass starvation of the forming fibers and to allow the surface glass to be slowly pulled into the enlarged main stream of attenuation without accidental pinch-off. Such a deliberate and slow rate of pull should continue until the underside of the plate is unflooded and separation is obtained. At this point, it is again necessary to prevent fiber starvation and pinch-off by an increase in the glass flow rate through the orifices by a slight warming to the plate. As the warming of the thermic gate proceeds to permit a renewed but limited flow rate through the individual orifices, the glass fibers which extend therefrom can be wound around a very slowly rotating collet. The rotational speed of the collet and the temperature of the plate which

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controls the flow therethrough can be simul-
taneously and gradually increased while the
air cooling (to be discussed) can be coordin-
ately reduced in pressure until a maximum
drawing speed at a maximum temperature is
reached.
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During operation, as glass passes through
an orifice, a stress is provided by the forces
of attenuation which are resisted by the vis-
cosity drag of the glass through the cone, the
base of which is fastened to the rim of the
orifice by surface tension, the wetting energy
of the glass and the partial vacuum inside
the cone. Through this dynamic sucking
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stress, more glass is pulled through the orifice
than would flow by gravity alone and there
is a continuous flow of glass toward the fila-
ment and flooding is avoided.
15
As hereinafter noted, to maintain an asymp-
totic geometry of the fiber forming cones and
therefore maintain separation of the indi-
vidually formed fibers, it is necessary to cool
substantially identically each of the fibers and
the fiber forming cones as well as maintain
the proper correlation between the rate of
withdrawal, the temperature of the orifice
plate and the flow rate through the individual
orifices. In order uniformly to cool each of
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the individual fibers and cones, an air source
is disposed below the orifice plate. The dis-
tance of the source from the plate depends
upon the area of the orifices, size of the air
nozzle or nozzles and the like. The distance
is generally between 1 and 20 inches (2.5cms—
51cms) and with the particular size nozzle
described below is between 2 and 4 inches
(5cms—10cms). Preferably the upwardly
moving air is introduced at a distance of from
about 2 to about 12 inches (5cms to 30.5cms)
25
from the bushing. With larger orifice areas
the source of upwardly moving air will often
be at least about 4 inches (10cms) from the
plate so that the air stream readily can impact
on the entire orifice area.
30
The upwardly quenching air flow moves
in between the individual fibers to each of
the hundreds or thousands of cones. There
is considerably more open space than space
occupied by glass fibers below an orifice plate.
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Despite the small area occupied by the
fibers, the fast moving filaments will entrain
the air and begin to function as an air pump.
Within the first fractions of an inch (a cm)
from the orifices, however, the skin drag
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of the fibers is unable to accelerate the skid-
ding air vortices thereby to a speed at which
this entrainment pump becomes effective. But
as the fibers are brought closer together and
the air skids faster and faster along the fiber
boundary layers, this pumping effect rapidly
increases.
45
When the ascending turbulent air reaches
the interstices between the orifices, it splits
to form a hexagonal star, the moving points

of which flow toward the area between the
fibers while the remainder is perfectly pro-
portioned, providing even 360° cooling of the
fiber forming cones. As this cool air turns
downwardly, hugging the convex shape of the
cone as well as hugging and skidding the full
fiber length, it accelerates to a very high speed
as it follows the filament into the high pump-
ing zone. A continuous mixing of cool ascend-
ing air with hot turbulent air in the vortices
caused by the skin effect surrounding the
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descending fibers provides a uniform and
stable environment over the entire length of
the formed fiber.
The upwardly directed air, in addition to
cooling the surface of the cones and providing
air to be drawn down the fibers, also serves
to prevent pockets of stagnant air on the
underside of the bushing which can result in
local hot spots and cause flooding. The
upwardly directed bulk air movement impinges
on the underside of the bushings and tests
indicate that a portion of that air moves
laterally outwardly in all directions from the
orifice area. The macro-cooling with the
upwardly moving bulk air establishes and
maintains cone and fiber separation.
80
Diametrically opposed to a conventional
bushing with tips, it has been determined
that, at a constant windup speed and constant
plate temperature, more cooling by the air
will provide a larger diameter fiber. Appar-
ently the skin cooling in the cone creates a
pumping action as the fiber is drawn from
the cone.
85
In proper operation the cone lengths are
stable to the eye and the visual length of the
cone is very short, generally not more than
about 2—1/2 times the orifice diameter and,
in any event, generally not longer than about
1/8 inch (3.2mm). In preferred operation the
cone length is not more than about 1—1/2
times the orifice diameter. Many times, the
pumping action caused by the cooled skin of
the cone results in the base of the cone reced-
ing part way up the side of the orifice in the
bushing. The glass temperature at the tip of
the cone will be approximately the annealing
temperature of the glass, and generally will be
from about 1400°F (760°C) to about 1700°F
(927°C).
90
The angle of air flow will vary somewhat
depending on the number of rows and the
density of orifices. Generally, process control
is best maintained by positioning the air as
vertical as possible consistent with the needs
to draw fibers. While with extremely close
control, the air may be directed upwardly at
an angle of about 40° from horizontal, tests
with a 17 row orifice plate and a 10 row orifice
plate have indicated that for realistic control
100
in commercial operation, the angle of the air
should be at least 45 or 46 degrees from the
horizontal, but preferably at least 60 degrees
from the horizontal. With only a few rows
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110
115
120
125

the angles may be somewhat less critical. Air angles of from 70 to 85° are particularly preferred. The term horizontal is employed here to mean the plane in which the orifice plate generally lies.

Any mechanical arrangement that provides a bulk flow of air (i.e., a generally single upwardly moving air column at the cone and plate area) that impinges on the orifice plate is satisfactory for this invention. Multiple nozzles or a nozzle with a slit can be employed. Deflector plates which deflect air to an upward path can also be employed. While introduction of the upwardly moving air from one side of the orifice plate is entirely satisfactory and is preferred, the air can, if desired, be introduced from two or more sides of the bushing. The cross-sectional size of the air stream at the orifice plate should be at least as large as the orifice area in the orifice plate. The fibers can be pulled somewhat off to one side to accommodate the mechanical arrangement for introducing the air. The same benefit can be obtained by pulling the fibers vertically and tilting the bushing slightly.

The air pressures to be employed may readily be determined by routine trial and experiment and may vary from 2 inches (5cms) of water to 5 psig or 10 psig (0.35Kg/cm² or 0.7 Kg/cm² above atmospheric pressure) or more depending on nozzle size, nozzle location and the like. Pressures from about 1 to about 5 psig (0.07 to 0.35 Kg/cm² above atmospheric pressure) are generally preferred, particularly for bushing of 10 rows or more. Generally the linear velocity of the air leaving the nozzle will be at least about 100 feet (30.5m) per second and preferably at least about 200 feet (61m) per second. Air velocities on the order of 400 feet (122m) per second and higher are readily employed in this invention. The velocity or pressure chosen, as noted above, will depend, in part, on the particular arrangement chosen. In any event the air flow should be sufficient to cool the cones and provide stable separated cones, to impinge on the plate essentially to eliminate stagnant air adjacent the plate and to provide a source of gas sucked downwardly by the fibers. It is apparent that cooling should not be so pronounced that fiber production is materially adversely affected.

While the above represents the preferred embodiment of cone stabilization, another method of in-mass cooling is provided by a series of thin curtains of cool air which sweep across orifice plate in rapid succession and are directed at an angle of 46° to 90° to the plate. Other variations in cooling such as the utilization of a staccato series of controlled annular vortices moving onto and generally normal to the face of the bushing can also be incorporated.

Similarly, spiraling air currents could be employed whose vortices rotate generally in a

plane with the plate similar to that produced by a fan blade.

The close orifice spacing and the stability of the cones can result in self-correction of localized flooding, should such flooding occur during operation. If a fiber breaks and the orifice floods to an adjacent fiber, that fiber will exert an increasing amount of attenuating force on the flooded glass to reinstitute cone and fiber formation from the flooded orifice. If necessary, localized cooling air as known in the art, for example, from a hand air lance may be applied to the multiple coalesced fibers to correct the flooding and reinstitute normal operation.

A slight instability may appear in the cones along the periphery of the orifice area. This occurs because the plate and glass are cooler due to heat losses to the exposed edges of the bushing. Stability can be improved providing the peripheral orifices are made slightly larger (for example, from about 0.001 to about 0.003 inches (0.02mm to 0.07mm) in diameter larger) than the interior orifices. Such adjustment will provide a more stable operation without materially affecting uniformity of fiber size. Since the volume of glass, not just its skin, flowing through the peripheral orifices is cooler, glass will flow through the orifice less readily so that use of a slightly larger orifice will compensate for the reduced ability of the glass to flow.

In order to insure that molten glass from an orifice will controllably flood if the fiber breaks, one embodiment of this invention contemplates the provision of capillary grooves between orifices. These capillary grooves will cause the plate to act as though it had a controlled but perfect wettability. In this embodiment, each orifice is joined to at least two adjacent orifices so that if a fiber breaks, controlled flowing of the glass to the adjacent orifice is virtually assured. The grooves may have the same width as the diameter of the orifices but preferably their width is about one-third of the diameter of the orifice and the grooves may have a depth of around one-half of the thickness of the bushing plate. Since the outer orifices may tend to flood more often than interior orifices, only outer orifices may be provided with grooves. Viewed in the context of start-up and self-correction of flooding, a bushing made of highly wettable alloy, which more easily floods, is preferable to a bushing made of a so-called non-wettable alloy. All alloys, of course, will flood if the temperature of the glass is sufficiently high to cause the glass to be quite fluid.

The cooled fibers are coated with a dressing fluid or sizing by contacting the fibers with an applicator roll or the like, and the fibers they may be wound up on a package. The drawing or windup speeds of the fibers may vary widely from, for example, of about 100 ft. (30.5m) per minute up to about

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13,000 ft. (4000m) per minute or more. Determination of wind-up speeds or attenuation force for any given set of conditions is within the skill of the art. Windup speeds of over about 5,000 feet (1524m) per minute are employed in conventional processes and may readily be employed here. Low draw off speeds may permit matching of fiber production with the rate of fiber usage in the manufacture of a final product so that the fiber or strand could be employed directly in the final production. In view of the orifice density such procedures would still be within the range of practical production. Dressing fluids, dressing fluid applicators and windup apparatus are conventional in the art and will not further be described here.

Good quality glass fibers are manufactured by the method of this invention. As a threshold matter, the extremely rapid quench of the molten glass below the orifices results in less loss of volatiles from the glass so that the glass composition of the fiber will closely conform to the glass composition in the glass bath. Moreover, this invention permits the production of tempered fibers. With a super quench due to the upwardly flowing air, the surface is cooled more rapidly than the interior glass and the temperature gradient is greater above the annealing temperature than below. As a result, the surface of the final fiber is under compression. In a conventional process employing long tips quite the reverse occurs. The temperature gradient is greater below the annealing temperature than above. In conventional processes, snap-out sometimes occurs wherein the fibers at temperatures below the annealing temperature all break substantially at the same time. Snap-out has been attributed to circumferential and length-wise temporary tensional forces. As noted earlier, snap-out has not been observed in the method of this invention, and logically so.

While a conventional glass furnace and auxiliary equipment readily can be employed in the practice of this invention an apparatus wherein the head of glass can be maintained independent of the level of the glass bath is shown in the attached drawings by way of example.

Figure 1 is a schematic view of the glass fiber filament production equipment.

Figure 2 is an enlarged plan view of the bushing and orifice plate illustrated in Figure 1, together with a fragmentary elevational view of the bushing.

Figure 3 is an enlarged sectional view including the bushing and orifice plate as illustrated in Figure 1.

Referring now in detail to the drawings, an apparatus 10 for producing glass fibers 12 is illustrated in Figure 1. As shown therein, a head of molten glass 14 is maintained within a bushing 16. The bushing is comprised of a tubular reservoir portion 18 which can be

square, rectangular or cylindrical in shape and an enlarged base portion 20 which terminates at the lower end thereof in a flat orifice plate 22. The orifice plate has a plurality of tightly spaced plain holes 24 therein. As an example, in a 2,000 hole orifice plate 2.7 inches (6.86 cms) square, the holes or orifices are .04 inches (0.1cms) in diameter and spaced .06 inches (0.152cms) from center line to center line. Typically, the lengths of the holes in the orifice plate vary from .03 inches (0.07cms) to .06 inches (0.152cms) and T-shaped reinforcing bars 26 or, alternatively, a honeycomb structure (not shown) may be provided on the orifice plate to add strength thereto and to prevent plate sag. It is also entirely feasible to employ a generally flat orifice plate without any reinforcing.

A valve 28 which communicates the interior of the bushing with a liquid glass supply 30 can be disposed atop bushing 16 to permit a change in fiber diameter, with high heads tending to provide somewhat larger filaments. By opening and closing valve 28, glass is allowed to flow from the supply 30 into the reservoir portion of the bushing 16 thereby maintaining the desired head of the glass within the bushing.

To facilitate the regulation of the glass head within the bushing, an elongated platinum tube 32 extends upwardly from the interior of the bushing, through valve 28 to a sonic depth indicator 34. The sonic depth indicator is coupled with a valve regulator 36 which reacts to signals therefrom to move the valve 28 upwardly or downwardly on the bushing thereby opening and closing the valve and allowing the liquid glass to pass thereby.

In the embodiment illustrated in Figure 1, the valve 28 is in threaded contact with regulator 36 by means of a threaded bar 37. Rotating the bar 37 causes the valve to move vertically with respect to valve seat 39 thereby regulating the flow of glass into the bushing 16. In this manner, a desired head of glass is continually maintained within the bushing as the glass fibers are drawn through the orifices 24 in the orifice plate 22.

As shown in Figure 1, a platinum bus bar 38 communicates with an electrical source of about 3 volts and 1,000 amps with the orifice plate whereby the temperature of the plate can be increased. A water cooled copper bus bar 40 is provided on the platinum bus bar 38 to make the electrical contact between the platinum bus bar 38 and the electrical source and reduce the necessary length of the platinum bus bar thereby reducing costs. The copper bus bar 40 is water cooled to reduce the temperature at the point of contact between the two bus bars and thereby preserve the copper and is spaced a minimum distance of about 1.5 inches (3.8cms) from the orifice plate 22 so as to have a minimal effect on the temperature of the plate while

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limiting the length of the platinum bus bar. It can be seen that by controlling the electrical flow through a regulator, the temperature of the orifice plate can be carefully regulated. As an alternative to the above described plate heating method, it should be noted that the temperature of the orifice plate can also be controlled through induction heating without the need for the aforesaid bus bars. In general, orifice plate temperatures will range from about 2050°F (1120°C) to about 2300°F (1260°C) during operation. Generally, the orifice plate temperature is at least 50°F (28°C) below the molten glass temperature of 2100° to 2400°F (1150—1315°C) referred to previously.

Upwardly directed air 49 flows through nozzle 45 disposed on the end of supply hose 47, through connection 44. A row of nozzles can, of course, be employed to provide a substantially single column of air that impinges on the orifice plate and cools the cones to maintain them in a stable configuration. The attenuation of the fibers is effected by rotating drum 42.

As shown in Figures 1 and 3, the base portion of the bushing is surrounded by a ceramic support 46 which, in addition to providing support for the bushing, further insulates the exterior position thereof which is adjacent the orifice plate. The ceramic support 46 and tubular reservoir portion 18 of the bushing are surrounded by a layer of insulation material 48 which additionally extends between the platinum copper bus bars and the supply of liquid glass. The insulation material 48 terminates short of the walls of the bushing to provide an annular area 50 about the reservoir portion of the bushing in which a heating coil 52 is disposed to provide compensation for heat loss due to conduction through the insulation. The heating coil is connected to a thermocouple to control the current therethrough and thereby regulate the compensating heat generated thereby. A second layer of insulation material 54 is disposed over and spaced from the liquid glass supply 30 thereby providing an insulation gap 56; as shown in Figure 1. Of course, the above represents merely an exemplary embodiment of an insulation and supplementary heating configurations and other varying configurations could be employed to adequately maintain the desired temperatures. For example, to compensate for heat loss from the bushing due to conduction, resistance heating could be employed using the bushing as an element of an isolated circuit. In such an embodiment, a 400 cycle generator has been found to be an excellent power source.

Lastly, as shown in Figure 1, a sizer 58 is provided to size the individual fibers with a

standard lubricant type material such as starch to reduce abrasion between adjacent fibers and to assist resin wetting for future laminating. A roll sizer may also be employed to reduce consumption of sizing.

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

EXAMPLE I

A conventional tipless bushing was employed in this example made from 0.040 inch (1.0mm) thick platinum alloy (80% platinum—20% rhodium) flat sheet. Orifices 0.052 inches (1.32mm) in diameter were drilled in the flat plate in a hexagonal pattern on 0.070 in. (1.78mm) centers. The rectangular orifice area in the bushing was approximately 1.25 in. (3.125cms) wide and approximately 2.85 in. (7.24cms) long with alternating 17 and 18 orifice rows. Each row contained about 46 orifices.

Type E glass was melted in a conventional glass furnace to provide about a 10 in. deep glass bath having a temperature of approximately 2300°F (1260°C) and glass fibers were manufactured employing the above plate. The plate was equipped with a heater and maintained a temperature of about 2100°F (1149°C). A standard sizing was applied by a roll to the fibers which were wound at a speed of about 3,000 ft. (914.4 metres) per minute.

In order to maintain fiber separation, air was directed upwardly from the long side of the orifice area at an angle of approximately 15 degrees from vertical through six 1/4 in. (0.61cms) diameter nozzles arranged in a row on one side of the orifice area about 5 inches (12.70cms) below the orifice plate. Air pressure within the range of 3—5 psig (0.21 to 0.35 Kg/cm² above atmospheric pressure) was employed.

Fibers were successfully drawn in stable operation and filament separation was maintained.

During usage of orifice plate exhibited from warpage and developed both concave and convex areas. The warpage of the orifice plate did not hamper fiber manufacture.

EXAMPLE II

In order to illustrate the benefits of this invention, the performance of the orifice of Example I is compared to the performance of two conventional tip bushings, (designated A and B) employing fin coolers. The overall bushing face areas were the same in each case but the orifice section of the bushing of Example I covered less than 1/4 of the entire face of the bushing. In each case Type E glass was used.

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		Bushing		
		EX. I	A	B
	No. Holes	804	390	390
	Hole Dia.			
	(in.)	.052	.078	.090
	(mm)	1.32	1.98	2.286
	Throughput			
	(lb/hr)	65.0	39.0	51.6
	(Kg)	29.5	17.7	23.40
	Area of			
	Each Hole			
	(in ² × 10 ⁴)	21.23	47.78	63.62
	(cm ²)	137	308.26	410.45
	Hole Area Ratio	1	2.25	3
	Orifice Plate Area			
	(in ²)	3.56	15.62	15.62
	(cm ²)	23	100.77	100.77
	Throughput			
	(lb/in ² /hr)	18.3	2.5	3.3
	(gm/cm ² /hr)	1282	176	232
	Holes per			
	inch ² of			
	Bushing	226	25	25
	Holes per			
	cm ² of			
	Bushing	35	4	4

The above demonstrates that this invention provides more throughput per unit of bushing area in the bushing as compared to conventional practice. This invention also provides more throughput per hole area as compared to conventional practice. More clearly to envision the magnitude of difference, if an equal size of orifice section were used, Example I bushing would have produced 3527 fibers with a throughput of 285 pounds (129 Kg) per hour.

EXAMPLE III

The bushing employed in this example was made from a 0.060 inch (1.52mm) thick platinum alloy (80% platinum—20% rhodium) flat sheet. One thousand six hundred and seventy orifices were drilled in the flat plate in a hexagonal pattern on 0.070 inch (1.78mm) centers. The rectangular orifice area in the bushing was approximately 1—1/8 inch (2.86cms) wide and approximately 6—1/2 inches (16.51cms) long. The peripheral orifices were 0.049 inches (1.245 mm) in diameter and the remaining orifices were 0.047 inches (1.19mm) in diameter.

Type E glass was melted in a conventional glass furnace to provide about a 10 inch deep glass bath having a temperature of approximately 2300°F (1260°C) and glass fibers were manufactured employing the above plate. The plate was equipped with a heater and maintained a temperature of about 2240°F (1227°C). A standard sizing was applied by a roll to the fibers which were wound at a speed of about 2,500 feet (762 metres) per minute.

In order to maintain fibre separation, air was directly upwardly from the long side of the orifice area at an angle of approximately 20 degrees from vertical through twelve 1/4 inch (0.61cms) diameter nozzles arranged in a row on one side of the orifice area about 5 inches (12.70cms) below the orifice plate. Air pressure within the range of 3—5 psig (0.21 to 0.35 Kg/cm² above atmospheric pressure) was employed.

Fibers were successfully drawn in stable operation and filament separation was maintained. The peripheral cones were quite stable.

WHAT WE CLAIM IS:—

1. A method of forming glass fibres which comprises maintaining heat-softened glass at a perforated area of a metallic plate formed with orifices which open to and terminate at the outer face of the plate, extruding separate streams of molten glass through the orifices in the orifice plate, drawing glass fibres from the streams of heat-softened glass formed at each orifice, and directing a flow of gas into contact with the outer face of the orifice plate so as to maintain said outer face at a temperature below the temperature of the heat-softened glass at said perforated area and to maintain the streams of glass associated with the individual orifices as separate streams.

2. A method according to Claim 1, wherein the outer face of the orifice plate is maintained at a temperature at least 50°F (28°C) below the temperature of the heat-softened glass.

3. A method according to Claim 1 or 2, wherein the orifice plate is maintained at a temperature of from 2050°F (1120°C) to 2300°F (1260°C).

4. A method according to any of claims 1 to 3 wherein the streams of glass are passed through an orifice plate in which the openings of the orifices at the outer face of the orifice plate lie in the plane of said outer face.

5. A method according to any of claims 1 to 4, wherein the streams of glass are passed through an orifice plate in which there are a number of closely spaced spinning openings.

6. A method according to any of claims 1 to 5 wherein the streams of glass are passed downwardly through a substantially horizontal orifice plate, the flow of gas is directed upwardly into contact with the outer face of the orifice plate, and the glass fibres are drawn downwardly from the outer face of the orifice plate.

7. A method according to any preceding claim, wherein the direction in which the flow of gas is directed into contact with the orifice plate is substantially opposite to the direction in which the glass fibres are drawn.

8. A method according to any preceding claim, wherein the glass is supplied to a



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	EX. I	A	B
No. Holes	804	390	390
Hole Dia. (in.)	.052	.078	.090
(mm)	1.32	1.98	2.286
Throughput (lb/hr)	65.0	39.0	51.6
(Kg)	29.5	17.7	23.40
Area of Each Hole (in ² × 10 ⁴)	21.23	47.78	63.62
(cm ²)	137	308.26	410.45
Hole Area Ratio	1	2.25	3
Orifice Plate Area (in ²)	3.56	15.62	15.62
(cm ²)	23	100.77	100.77
Throughput (lb/in ² /hr)	18.3	2.5	3.3
(grm/cm ² /hr)	1282	176	232
Holes per inch ² of Bushing	226	25	25
Holes per cm ² of Bushing	35	4	4

The above demonstrates that this invention provides more throughput per unit of bushing area in the bushing as compared to conventional practice. This invention also provides more throughput per hole area as compared to conventional practice. More clearly to envision the magnitude of difference, if an equal size of orifice section were used, Example I bushing would have produced 3527 fibers with a throughput of 285 pounds (129 Kg) per hour.

EXAMPLE III

The bushing employed in this example was made from a 0.060 inch (1.52mm) thick platinum alloy (80% platinum—20% rhodium) flat sheet. One thousand six hundred and seventy orifices were drilled in the flat plate in a hexagonal pattern on 0.070 inch (1.78mm) centers. The rectangular orifice area in the bushing was approximately 1—1/8 inch (2.86cms) wide and approximately 6—1/2 inches (16.51cms) long. The peripheral orifices were 0.049 inches (1.245 mm) in diameter and the remaining orifices were 0.047 inches (1.19mm) in diameter.

Type E glass was melted in a conventional glass furnace to provide about a 10 inch deep glass bath having a temperature of approximately 2300°F (1260°C) and glass fibers were manufactured employing the above plate. The plate was equipped with a heater and maintained a temperature of about 2240°F (1227°C). A standard sizing was applied by a roll to the fibers which were wound at a speed of about 2,500 feet (762 metres) per minute.

In order to maintain fibre separation, air was directly upwardly from the long side of the orifice area at an angle of approximately 20 degrees from vertical through twelve 1/4 inch (0.61cms) diameter nozzles arranged in a row on one side of the orifice area about 5 inches (12.70cms) below the orifice plate. Air pressure within the range of 3—5 psig (0.21 to 0.35 Kg/cm² above atmospheric pressure) was employed.

Fibers were successfully drawn in stable operation and filament separation was maintained. The peripheral cones were quite stable.

WHAT WE CLAIM IS:—

1. A method of forming glass fibres which comprises maintaining heat-softened glass at a perforated area of a metallic plate formed with orifices which open to and terminate at the outer face of the plate, extruding separate streams of molten glass through the orifices in the orifice plate, drawing glass fibres from the streams of heat-softened glass formed at each orifice, and directing a flow of gas into contact with the outer face of the orifice plate so as to maintain said outer face at a temperature below the temperature of the heat-softened glass at said perforated area and to maintain the streams of glass associated with the individual orifices as separate streams.

2. A method according to Claim 1, wherein the outer face of the orifice plate is maintained at a temperature at least 50°F (28°C) below the temperature of the heat-softened glass.

3. A method according to Claim 1 or 2, wherein the orifice plate is maintained at a temperature of from 2050°F (1120°C) to 2300°F (1260°C).

4. A method according to any of claims 1 to 3 wherein the streams of glass are passed through an orifice plate in which the openings of the orifices at the outer face of the orifice plate lie in the plane of said outer face.

5. A method according to any of claims 1 to 4, wherein the streams of glass are passed through an orifice plate in which there are a number of closely spaced spinning openings.

6. A method according to any of claims 1 to 5 wherein the streams of glass are passed downwardly through a substantially horizontal orifice plate, the flow of gas is directed upwardly into contact with the outer face of the orifice plate, and the glass fibres are drawn downwardly from the outer face of the orifice plate.

7. A method according to any preceding claim, wherein the direction in which the flow of gas is directed into contact with the orifice plate is substantially opposite to the direction in which the glass fibres are drawn.

8. A method according to any preceding claim, wherein the glass is supplied to a



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container where it is maintained in molten form, the glass is withdrawn through an orifice plate disposed at the bottom of the container, and the glass is heated at least in a region adjoining the orifice plate sufficiently for it to be passed through the orifices.

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9. A method according to any preceding claim, wherein the glass is passed through an orifice plate in which there is at least one group of closely spaced orifices.

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10. A method according to any preceding claim, wherein the glass is passed through the orifice under pressure.

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11. An apparatus for manufacturing glass fibres, comprising a container for molten glass, an orifice plate disposed at the base of the container and formed with orifices which open to and terminate at the outer face of the plate, means for drawing glass fibres from streams of molten glass passing through the orifices in the orifice plate, and means for directing a flow of gas onto the external surface of the orifice area of the orifice plate at such a velocity and such a volume that the outer face of the orifice plate is cooled to a temperature below the temperature of the molten glass at the inlet end of the orifices and the streams of molten glass associated with the individual orifices are maintained as separate streams.

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12. An apparatus according to claim 11 further comprising means for supplying controlled amounts of glass to the container.

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13. An apparatus according to claim 11 or 12 further comprising a heater for heating the glass in the container so as to maintain the glass in a molten state at least in the region adjacent the orifice plate.

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14. An apparatus according to any of claims 11 to 13 further comprising a regulator for regulating the flow of gas whereby the temperature of the outer face of the orifice plate may be maintained at the appropriate value.

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15. An apparatus according to any of claims 11 to 14, wherein the orifice plate has a thickness not greater than 0.06 inches (1.52 mm).

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16. An apparatus according to claim 15 in which the orifice plate has a thickness of 0.040 inches (1.0 mm).

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17. An apparatus according to any of claims 11 to 16, wherein the diameter of the orifices in the orifice plate is from 0.020 inches (0.5 mm) to 0.1 inches (2.5 mm).

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18. An apparatus according to any of claims 11 to 17, wherein the diameter of the orifices in the orifice plate is 0.020 inches (0.05 mm).

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19. An apparatus according to any of claims 11 to 18, wherein the orifices are spaced apart at a centre-to-centre distance of 1.25 to 2 orifice diameters.

20. An apparatus according to any of claims 11 to 19 wherein the orifices are

spaced apart at a centre-to-centre distance of 2 orifice diameters.

21. An apparatus according to any of claims 11 to 20 additionally comprising means for applying pressure to the molten glass in the container.

22. A method of forming glass fibres which comprises:

(a) passing separate streams of molten glass through a plate having at least four rows of closely spaced orifices extending therethrough, the orifices opening to and terminating at the outer face of the plate and being spaced in flooding relationship;

(b) drawing fibres from cones of molten glass formed at each said orifice;

(c) directing a flow of rapidly moving gas upwardly to the orifice area in said plate, said flow being a generally single gas column at the cone and orifice area in an amount velocity and angle sufficient:

(i) to cool said cones to provide a stable cone formation and to maintain separation of cones thus preventing flooding;

(ii) to impinge on said plate essentially to eliminate stagnant gas adjacent said plate and to cause gas to move outwardly along said plate in all directions from said orifice area, and

(iii) to supply a source of gas to be sucked downwardly by the fibres; and

(d) heating the orifice plate by means of heating means associated therewith.

23. A method according to claim 22 in which the glass is passed through the orifices under essentially only the influence of a head of molten glass maintained above the orifice plate.

24. A method according to claim 22 or 23 wherein said gas flow is directed at an angle of at least 60° to said plate.

25. A method according to claim 24 wherein said gas flow is directed at an angle of at least 70° to said plate.

26. A method according to any one of claims 22 to 25, wherein the orifices are formed in the plate at a density of at least 50 orifices per square inch (per 6.45 cm²).

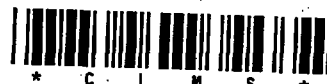
27. A method according to claim 26 wherein the orifices are formed in the plate at a density of at least 100 orifices per square inch (per 6.45 cm²).

28. A method according to claim 27 wherein the orifices are formed in the plate at a density of at least 200 orifices per square inch (per 6.45 cm²).

29. A method according to claim 27 or 28 wherein the orifice area has a minimum of at least 10 rows in each direction.

30. A method according to any one of claims 22 to 29 wherein the area occupied by orifices has a minimum dimension of 1.25 cms.

31. A method according to claim 30 wherein



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32. A method according to any one of claims 22 to 31 wherein said gas is a non-reducing gas.

33. A method according to any one of claims 22 to 32 wherein the gas flow is introduced from a single side of the area occupied by orifices.

34. A method according to any one of claims 22 to 33 wherein said gas flow is directed upwardly from a source at a distance of at least 2.5 cms from said orifice plate.

35. A method according to claim 34 wherein said gas flow is directed upwardly from a source at a distance of at least 5 cms from said orifice plate.

36. A method according to any one of claims 22 to 35 wherein the cones are maintained at not more than 3.2 mm long.

37. A method according to claim 36 wherein the length of said cones is not more than 2½ times the orifice diameter.

38. A method according to any one of claims 22 to 37 in which the gas column has a cross-section at the orifice plate at least as large as the area occupied by the orifices.

39. A method according to any one of claims 22 to 38 wherein the molten glass is initially passed through the orifice plate at a temperature and flow rate sufficient to flood the underside of the plate and the flow rate is then reduced to allow the flooded glass on the underside of the plate to be pulled therefrom as separate fibres depending from cones formed at the orifices.

40. A method according to claim 39 wherein the reduction of flow rate is obtained by lowering the temperature of the glass passing through the orifices to the edge of the glass devitrification temperature.

41. A method according to claim 40 in which the reduction in the flow rate is obtained by controlling the gas flow to the orifice area.

42. A method according to claim 40 or 41 in which the temperature of the molten glass is lowered from a temperature of from 1150 to 1315°C by 50°C to 150°C.

43. A method according to any one of claims 39 to 42 wherein the separated fibres produced by pulling the flooded glass from the plate are initially withdrawn at a rate of ¼ inch (1.27 cms) per second.

44. A method according to any one of claims 39 to 43 in which, after the flooded glass is pulled from the plate to produce separate fibres, the flow of glass through the orifices is increased and the bulk flow of moving gas is directed to the orifice area.

45. A method according to claim 44 wherein the increased flow of glass through the plate is obtained by increasing the temperature of the orifice plate.

46. A method according to claim 44 or 45 in which the temperature of the orifice plate

is gradually increased, the rate of fibre withdrawal is gradually increased to over 5000 feet (1524 m.) per minute and the pressure of upwardly directed gas is controlled in response to the increasing orifice plate temperature and rate of fibre withdrawal to maintain an asymptotic configuration of the cones.

47. A modification of the method claimed in any one of claims 22 to 45 in which the rapidly moving gas is directed upwardly to the orifice area of the plate at an angle of 46° to 90° thereto as thin curtains of gas which sweep across the plate in rapid succession.

48. An apparatus for manufacturing glass fibres comprising:

(a) means for containing a head of molten glass;

(b) a plate constructed of a heat resistant material and disposed at the base of said containing means, said plate having at least four rows of closely spaced orifices extending therethrough, the orifices opening to and terminating at the outer face of the plate and being spaced in flooding relationship;

(c) heating means associated with the orifice plate for heating said orifice plate;

(d) means for withdrawing fibres from the orifices in the plate and

(e) means disposed below said plate and being in communication with a gas supply for directing a bulk flow of rapidly moving gas upwardly towards said orifices as a generally single gas column at the cone and orifice area in an amount velocity and angle sufficient:

(i) to cool molten glass cones formed below the orifices during withdrawal of fibres therefrom to provide a stable cone formation and to maintain separation of cones thus preventing flooding;

(ii) to impinge on said plate essentially to eliminate stagnant gas adjacent said plate and to cause gas to move outwardly along said plate in all directions from said orifice area, and

(iii) to supply a source of gas to be sucked downwardly by the fibres.

49. An apparatus according to claim 48 wherein said gas directing means comprises a nozzle assembly and a conduit, said conduit communicating said assembly with said gas supply and said nozzle assembly being disposed from 1 to 20 inches (2.5 to 51 cms) below said plate.

50. An apparatus according to claim 48 or 49 including a bus bar in electrical contact with said plate and means for regulating the flow of electric current to said bus bar whereby the temperature of said plate can be controlled.

51. Apparatus according to claim 48, 49 or 50 wherein the means for maintaining a head of molten glass comprises a bushing assembly having a reservoir portion adapted to hold the head of molten glass therein and a base portion.

52. An apparatus according to claim 51



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including insulating means disposed about the bushing assembly and spaced from the reservoir portion thereof to define an insulating chamber, heating means disposed within said chamber and means for regulating the heating means to compensate for heat loss from said bushing assembly.

53. An apparatus according to claim 51 or 52 including a valve means disposed on said bushing assembly, said valve means communicating the reservoir portion of said assembly with a supply of molten glass and means for regulating said valve assembly.

54. An apparatus according to claim 53 including means for determining the depth of the head of glass within the reservoir portion of said bushing assembly and for generating a signal indicating said depth, and regulating means responsive to said signal for actuating said valve means to maintain a desired head of glass within said bushing.

55. An apparatus according to claim 54 including a second insulating means spaced from the supply of molten glass and being disposed between said supply and said regulating means.

56. An apparatus according to any one of claims 51 to 55 in which the orifice plate is disposed at the base portion of the bushing assembly.

57. An apparatus according to any one of claims 48 to 56 in which the orifice plate is constructed of a platinum alloy.

58. An apparatus according to any one of claims 48 to 57 in which the orifices at the periphery of the orifice area of the orifice

plate are slightly larger than the remaining orifices in the area.

59. An apparatus according to claim 58 wherein the orifice density is at least 50 orifices per square inch (6.45 cm²). 40

60. An apparatus according to claim 58 wherein the orifice density is at least 100 orifices per square inch (6.45 cm²). 45

61. An apparatus according to claim 58 wherein the orifice density is at least 200 orifices per square inch (6.45 cm²). 50

62. An apparatus according to any one of claims 48 to 61 in which the orifice plate is generally flat and formed with capillary grooves in the underside connecting adjacent orifices. 55

63. An apparatus according to claim 62 wherein each orifice is connected by grooves to at least two adjacent orifices. 60

64. An apparatus according to claim 63 wherein only the orifices near the periphery of the orifice area are connected by grooves. 65

65. A method of forming glass fibres substantially as hereindescribed with reference to the accompanying drawings. 60

66. Apparatus for forming glass fibres, constructed, arranged, and adapted to operate substantially as hereindescribed with reference to the accompanying drawings. 65

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