June 14, 1966 J. K. COCHRAN 3,256,079

METHOD AND APPARATUS FOR FORMING FIBERS

Original Filed June 13, 1960 6 Sheets-Sheet 1

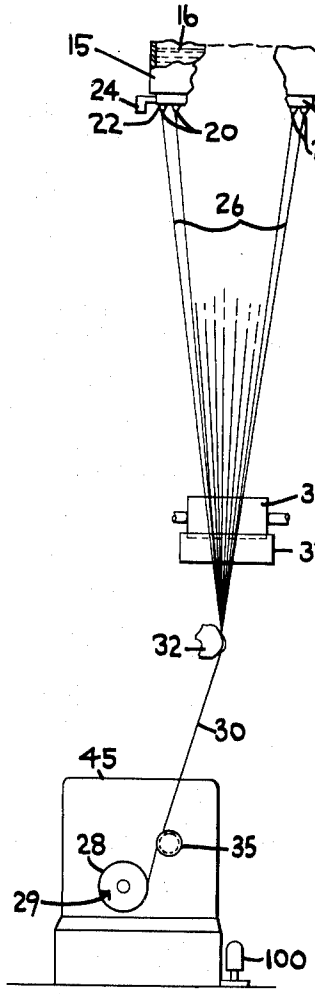


FIG. 1

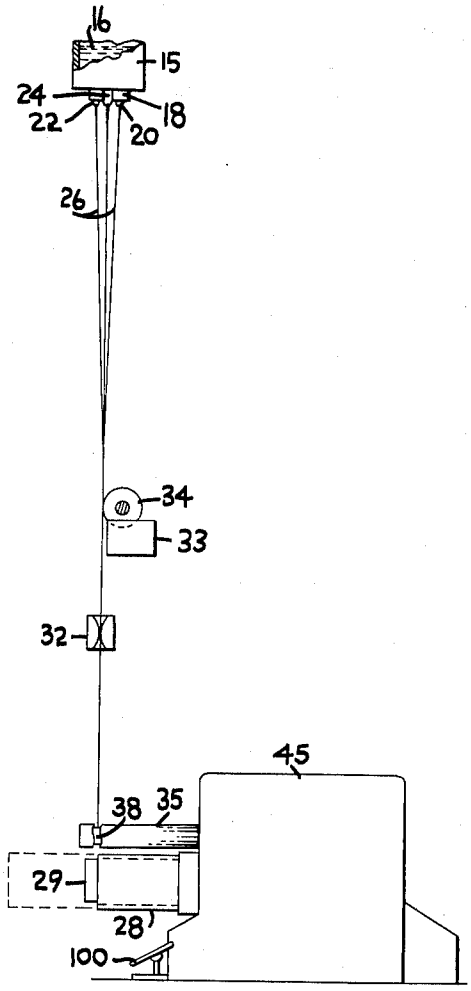


FIG. 2

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6 Sheets-Sheet 2

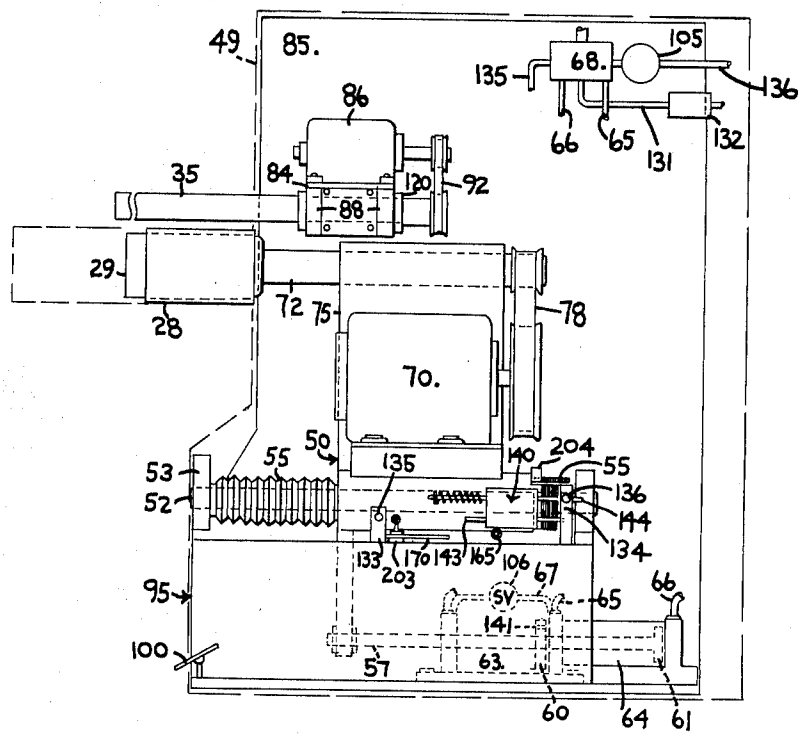


FIG. 3

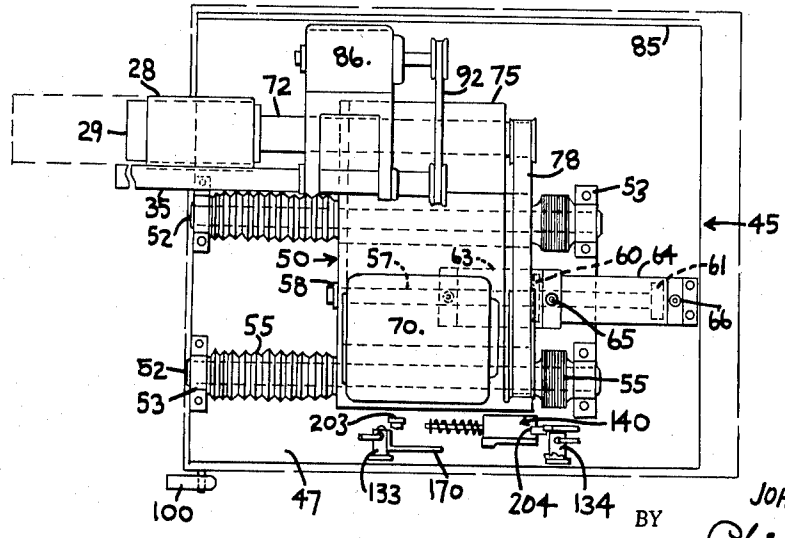


FIG. 4

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METHOD AND APPARATUS FOR FORMING FIBERS

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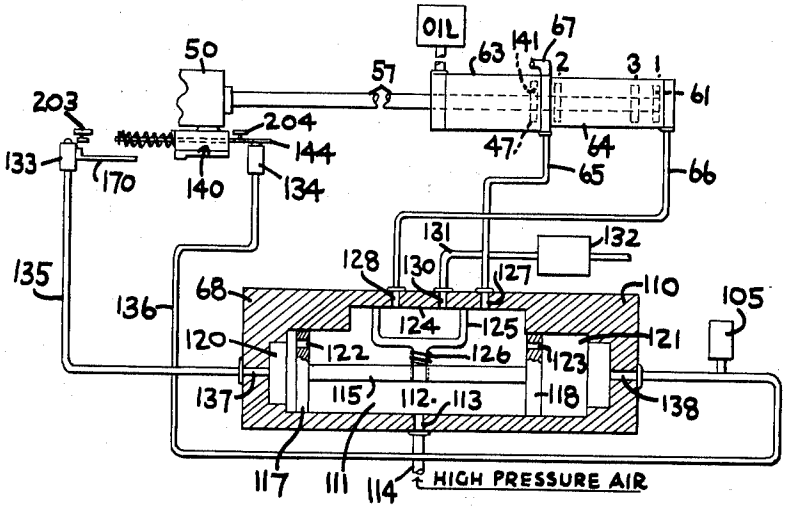


FIG. 6

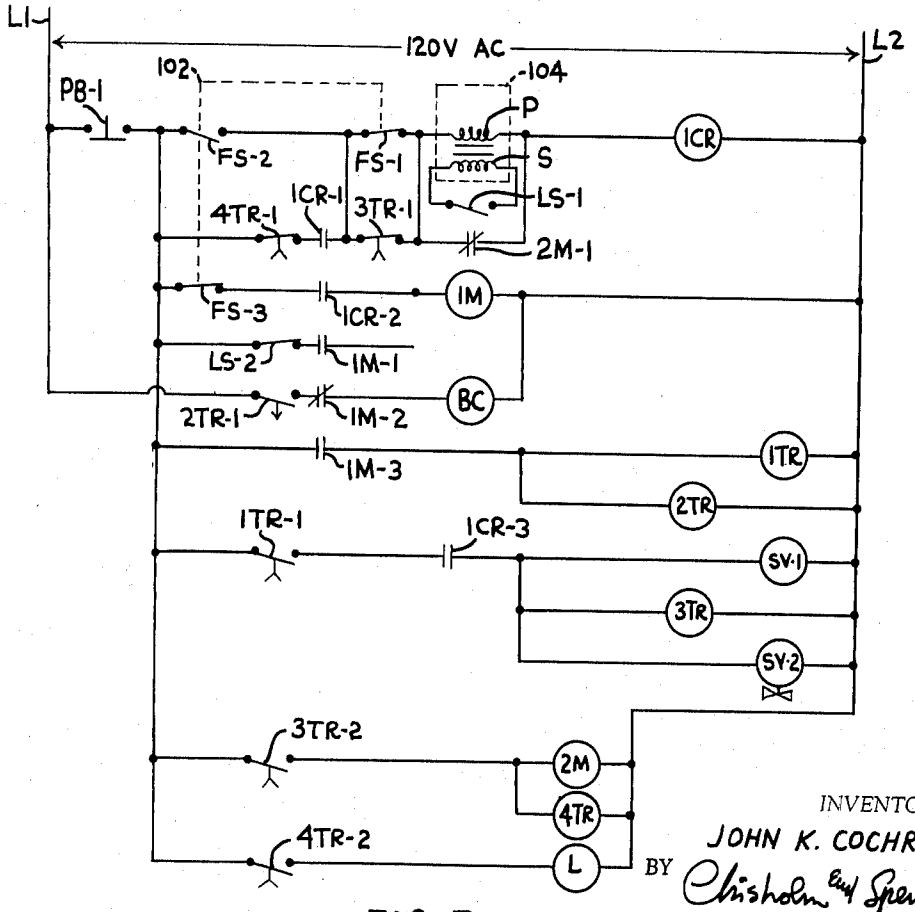


FIG. 5

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METHOD AND APPARATUS FOR FORMING FIBERS

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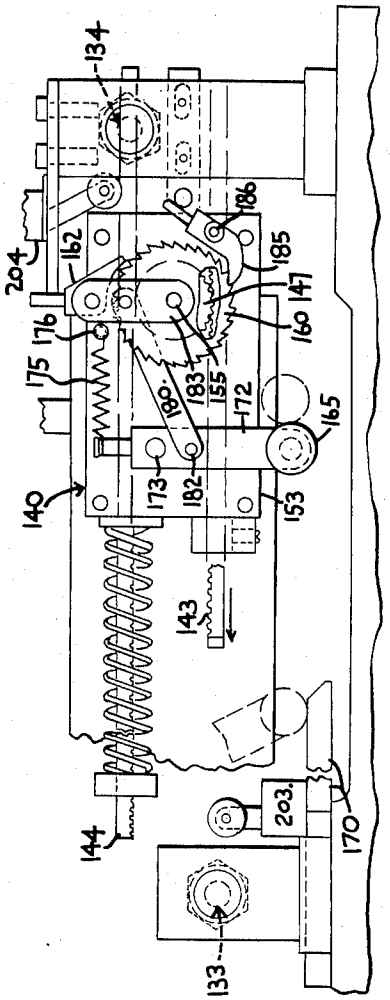


FIG. 7

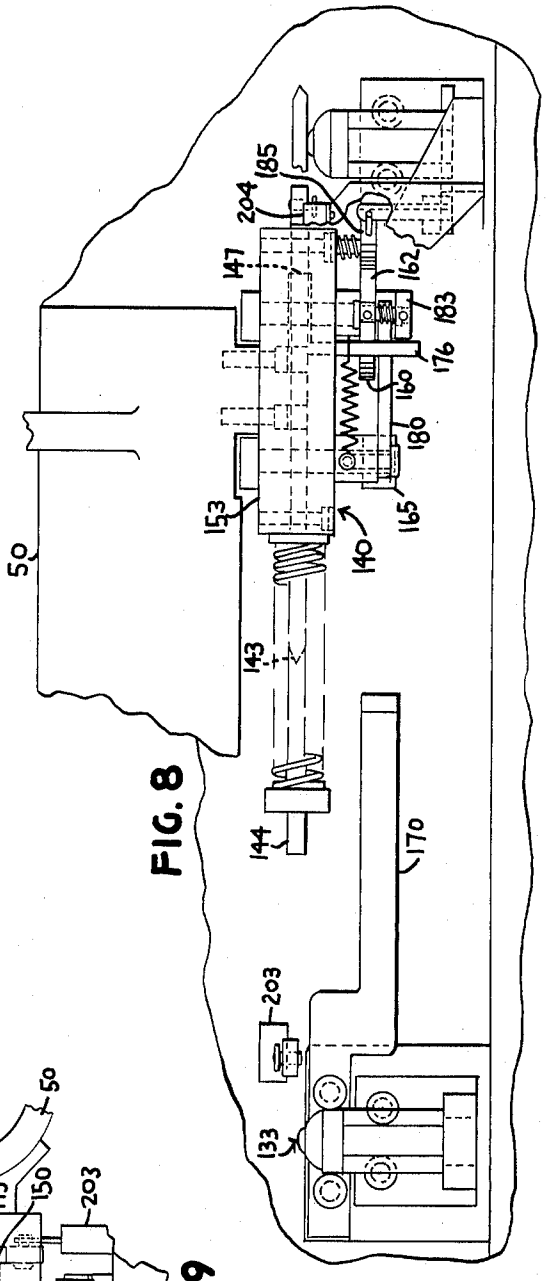


FIG. 8

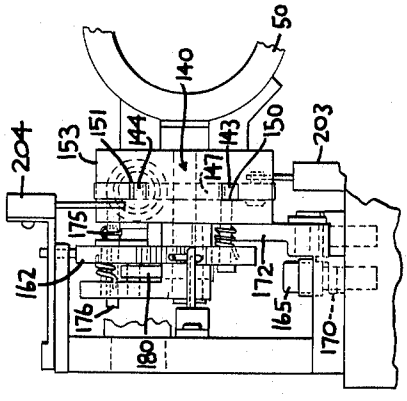


FIG. 9

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METHOD AND APPARATUS FOR FORMING FIBERS

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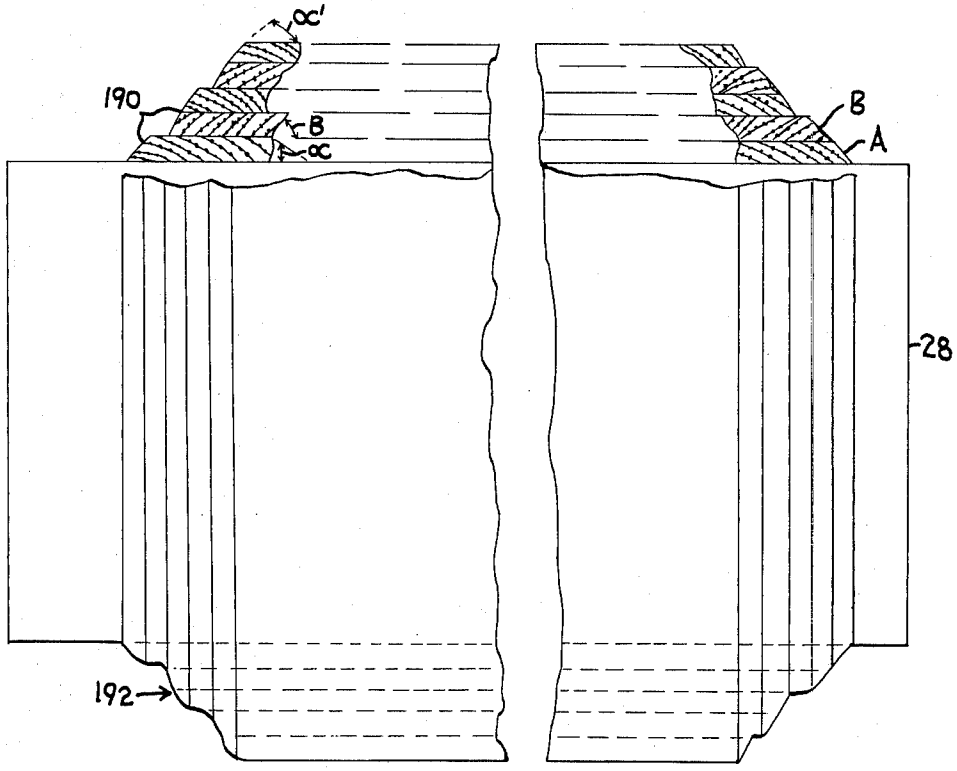


FIG. 10

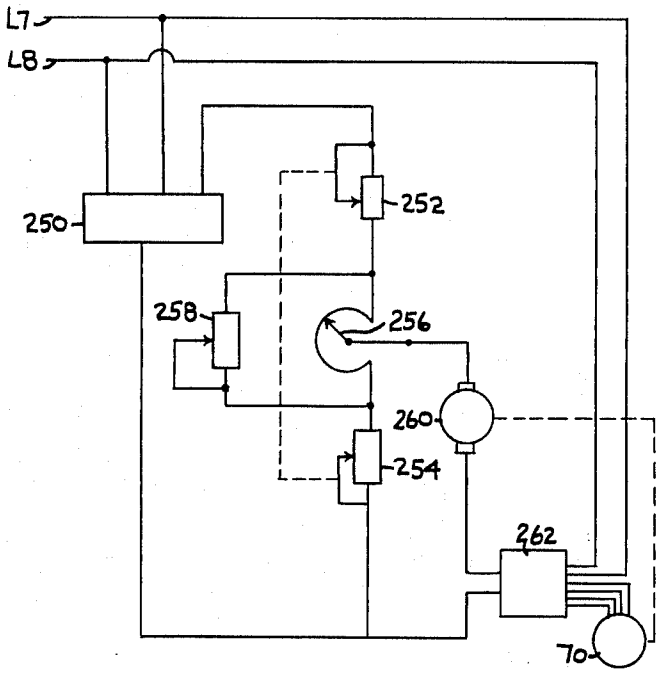


FIG. 13

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METHOD AND APPARATUS FOR FORMING FIBERS

Original Filed June 13, 1960 6 Sheets-Sheet 6

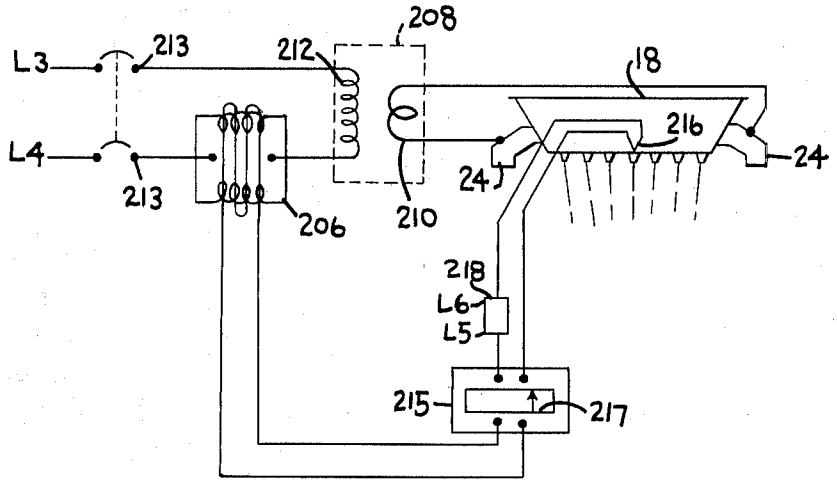


FIG. 11

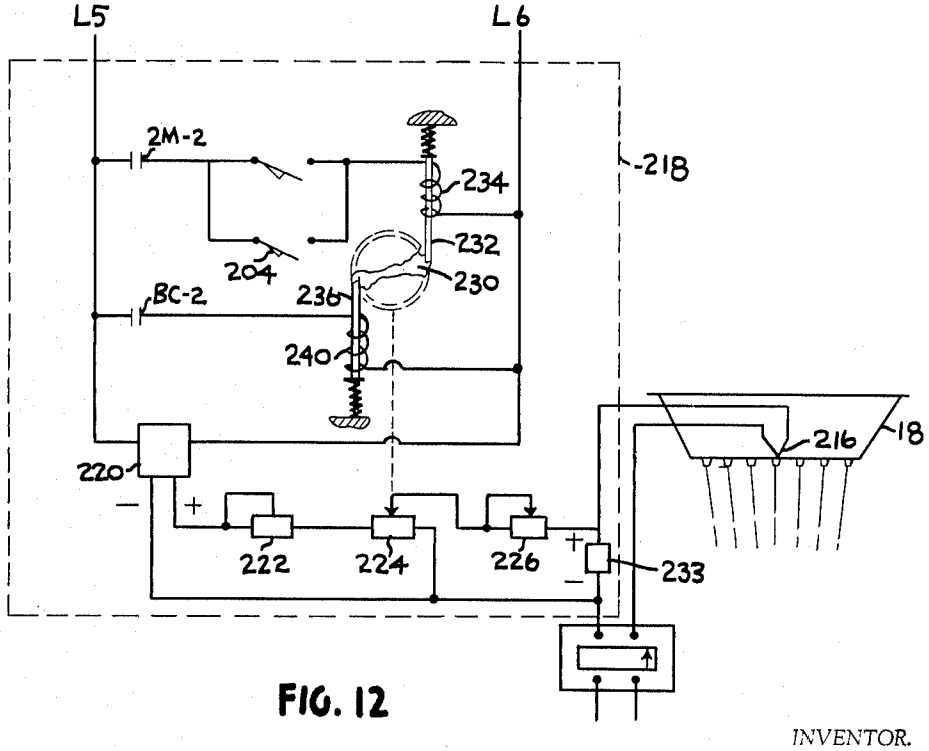


FIG. 12

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United States Patent Office 3,256,079 Patented June 14, 1966

3,256,079

METHOD AND APPARATUS FOR FORMING FIBERS

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Continuation of application Ser. No. 156,089, Nov. 30, 1961, which is a division of application Ser. No. 35,643, June 13, 1960. This application Oct. 8, 1964, Ser. No. 402,471

8 Claims. (Cl. 65—2)

This application is a continuing application of my copending application Serial No. 156,089, filed November 30, 1961, entitled "Textile Package and Method and Apparatus for Forming Same" now abandoned which, in turn, is a division of my application Serial No. 35,643, filed June 13, 1960, entitled "Textile Package and Method and Apparatus for Forming Same" now abandoned.

The present invention relates to a textile package and it has particular relation to a glass fiber strand forming package and to a method of and apparatus for producing the glass fiber strand forming package.

In the conventional process, continuous filament glass fibers are made in strand form by drawing a plurality of glass filaments through orifices in an electrically heated, platinum alloy bushing, gathering the filaments together in the form of a strand and winding the strand upon a forming tube mounted on a rotating cylinder called a collet. At the beginning of the fiber forming process, an operator pulls the individual filaments from the bushing by hand and groups them into a strand. The strand is passed over a gathering guide and is wound around one end of the collet beyond the forming tube. Rotation of the collet and forming tube is then begun. It takes several seconds for the collet to come up to the proper drawing speed and during this time the strand which is formed is of too great a diameter. When the proper drawing speed is attained, the strand is moved onto a traverse such as shown in United States Patent No. 2,391,870, and the strand is shifted by the traverse length-wise of the tube so as to be wound during the remainder of the run on the tube in an area which is spaced from the strand formed on the end of the collet during the start-up. When the forming run is completed, the strand is returned to the end portion of the collet containing the strand formed during start-up and wound thereon as the collet rotation returns to zero.

There is no twist in the strand as it is thus formed and a size is applied to the filaments prior to the winding of the strand on the tube in order to bond them together and maintain the integrity of the strand. An open wind has been used on the forming tube in order to aid removal of the strand from the tube. With this type of wind the succeeding turns of strand cross each other at substantial angles. The spiral wire traverse shown in United States Patent No. 2,391,870 has proved to be satisfactory for traversing a strand at the high rate of speed which is employed to wind the strand on a forming tube. The attenuating speed of the strand is usually about 10,000 to 15,000 feet per minute. The traverse, in addition to rotating about its own axis to provide a 3 to 5-inch throw per rotation, is reciprocated axially in order to distribute the strand over the length of the forming tube. The forming package produced with this type of traverse is barrel-like in shape with the ends of the package being tapered to substantially a single thickness of strand and with the center having the maximum diameter and thickness of package.

There are several factors such as glass head above the bushing, glass temperature and speed of drawing which

influence the size of the diameter of the strand during the fiber forming run. If these factors can all be kept constant during the run, a fiber of uniform diameter from the beginning to the end of the run can be produced. It has been conventional to use a collet and forming tube which rotate at a constant r.p.m. It can be seen that as the amount of strand is built up on the forming tube, the peripheral speed of the forming package increases during the fiber forming run and consequently the drawing speed of the strand is increased. Thus, unless there is some compensation made during the run to one of the variables mentioned above, the diameter of the strand formed at the end of the run will be smaller than the diameter of the strand formed during the beginning of the run.

Several methods have been suggested to solve the diameter size problem caused by rotating the collet at constant r.p.m. One method has been to increase the temperature of the molten glass in the bushing gradually during the fiber forming run, thereby gradually increasing the fluidity of the glass and permitting more glass to be attenuated as the run progresses. Another method has been to decrease the r.p.m. of the collet gradually during the run so as to maintain the peripheral speed of the forming package constant while the glass temperature is maintained constant. Both of these methods are discussed in greater detail in British Patent No. 774,339.

The above methods of compensating for the increased attenuation rate created by the increase in package diameter are only partial solutions to the problem when the strand is distributed on the forming tube by means of the traverse described in the aforementioned patent wherein a barrel-shaped forming package is produced. It can be seen with this type of traversing action, that as the strand is being wound around the ends of the forming package as contrasted to being wound around the center of the package, it is being drawn at a slower speed. This difference in drawing speed from the ends to the center of the package becomes greater as the diameter of the package in the center is increased during the drawing run. With this type of traversing mechanism and forming package, the strand differs considerably in diameter over each few feet of length and this difference becomes greater as the fiber forming run proceeds.

Another disadvantage to the type of forming package which is produced according to the method described above is that at the end of the run the strand may be located at any position along the length of the forming tube. This renders finding of the end very difficult. Much strand and time is wasted in finding the end so that the forming package can be unwound and the strand fabricated into roving or textile products.

A still further disadvantage to the forming package as described is that when it is unwound for further fabrication, the strand must be removed from the side of the forming tube rather than over the end of the forming tube. Attempts to remove the strand over the end of the forming tube result in entanglement of the strand and disruption of the unwinding process.

It is an object of this invention to provide a glass fiber forming package and method and apparatus for producing such package which permit the formation of a glass fiber strand of uniform diameter from the beginning to the end of the forming package. It is a further object of the invention to produce a forming package and methods and apparatus for producing the forming package which permit the finding of the end of the strand with a minimum of difficulty. It is still another object of the invention to produce a forming package which can be unwound over end without difficulty.

In accordance with the present invention, a glass fiber strand forming package is provided in which the strand

is wound in a series of superposed, parallel layers on the forming tube with the length of each succeeding layer being shorter than the length of each preceding layer. The strand is given a high frequency, low amplitude traverse as it is wound in each layer on the forming tube and the forming tube is reciprocated relatively slowly in an axial direction relative to the traversing means so as to form a separate layer approximately 0.01 to 0.05 inch in depth, preferably 0.025 to 0.035 inch in depth, with each axial movement of the forming tube. The length of the axial reciprocation of the forming tube is decreased with each layer so that each layer is terminated short of the preceding layer. As each layer is completed and a new layer is begun upon reversal of the movement of the forming tube, there is a short period where the strand overlaps into the two layers.

As each layer is completed and the next succeeding layer is begun, the bushing temperature is increased and/or the r.p.m. of the collet is decreased in order to compensate for the increased diameter of the forming package. Each succeeding layer is terminated short of the end of the preceding layer in order to keep the package diameter constant for that layer and also prevent entangling of the ends of each layer during unwinding of the strand. The present invention provides means for controlling the bushing temperature and/or collet r.p.m. in combination with means for controlling the relative movement between the forming tube and the traversing means to produce the successive parallel layers of strand on the package. It is understood, of course, that the traverse can be made to reciprocate with respect to a stationary forming tube, although it is preferred that the forming tube move relative to a stationary traverse and the invention will be further described with respect to the preferred embodiment.

The manner in which the objects of the invention are accomplished is described in further detail in conjunction with the drawings in which:

FIG. 1 is a diagrammatic elevation of the fiber forming apparatus;

FIG. 2 is a side view of FIG. 1;

FIG. 3 is an elevation of the winding apparatus;

FIG. 4 is a plan view of the winding apparatus shown in FIG. 3;

FIG. 5 is a schematic view of the electrical system for operating the winder of the invention;

FIG. 6 is a schematic drawing of the pneumatic system employed in the operation of the winder;

FIG. 7 is an elevation of the means for controlling the axial movement of the winder;

FIG. 8 is a plan view of the control means shown in FIG. 7;

FIG. 9 is a side view of the control means shown in FIG. 7;

FIG. 10 is a diagrammatic elevation partly in section of a forming package exemplifying the invention;

FIGS. 11 and 12 are diagrammatic views of a means for controlling the bushing temperature during the run in response to the control means shown in FIGS. 7, 8 and 9, and

FIG. 13 is a diagrammatic view of means for controlling the speed of the collet in response to the control means shown in FIGS. 7, 8 and 9.

In FIGS. 1 and 2 of the drawing, there is shown a glass melting container **15** or forehearth thereof containing a supply of molten glass **16** and having an electrically heated bushing **18** attached to the bottom of the container. The bushing **18** is trough-like in shape and is provided with a series of orifices **20**, which orifices are defined by tips **22** suspended from the bottom portion of the bushing. The bushing is composed of an alloy containing about 90 percent platinum and 10 percent rhodium and is heated by passing through it electric current from a suitable source. The current is passed through the bushing by means of terminals or lugs **24** attached to opposite ends of the bushing along the vertical end walls of the bushing.

The molten glass **16** within the bushing is maintained at a temperature suitable for fiberizing by means of heat transferred by conduction from the bushing to the glass contained therein. The molten glass flows through the tips **22** and forms in small cones **25** suspended from the tips. The tips are aligned in four or more rows having a great many tips in each row so that the total number of tips may be about 200 to 400. A smaller or greater number of rows or tips may be present in the bushing.

Glass filaments **26** are pulled from the cones **25** at a very high rate of speed, for example, 5,000 to 20,000 feet per minute, usually about 12,000 to 15,000 feet per minute, and wound on a rapidly rotating forming tube **28** mounted on a collet **29**. The collet may be approximately 6 to 8 inches in outside diameter and may rotate at approximately 6,000 to 8,000 r.p.m., depending upon the size of the fiber to be produced and other operating conditions such as the temperature of the glass in the cones **25**. The glass filaments **26** are grouped into a strand **30** as they pass over a guide **32** prior to being wound on the forming tube **28**.

Usually an aqueous size containing a liquid binder and a lubricant such as a combination of starch and a vegetable oil is applied to the individual filaments **26** of the strand **30** as they pass over a moving size applicator **33** which is mounted just above the guide **32**. The applicator may be in the form of a roller **34** or moving belt having a film of the size applied to it. The filaments pass over the roller or belt at some tangential point for momentary contact with the sizing solution to transfer the solution from the applicator to the filaments. An example of a suitable size applicator is shown in United States Patent No. 2,873,718.

As the strand **30** is wound on the tube, it is given a high frequency, low amplitude traverse by means of cam **35**. The cam **35** is in the form of a cylindrical spindle having a sinusoidal, peripheral groove **38** around its circumference. The walls **40** of the groove **38** are sloped inwardly at an angle of about 0 to 40 degrees to the axis of the spindle so as to reciprocate the strand **30** in the axial direction of the cam and collet very rapidly. The amplitude of the traversing movement is very slight and may be from $\frac{1}{16}$ to $\frac{1}{2}$ inch. The frequency of the traversing movement is controlled by the diameter of the cam **35**, the speed at which it is rotated and the number of reversals in the direction of the groove **38** as it travels around the periphery of the cam **35**. The cam **35** may have a diameter at the bottom of the groove of about 2 inches and a diameter at the top of the groove of about 2.5 inches and may have about 2 to 8 reversals in the groove. The cam may rotate at about 2,000 to 25,000 r.p.m. This provides the strand with a very slight traverse as it is wound on the forming tube **28**.

The strand is distributed along the length of the forming tube by relative motion of the forming tube **28** with respect to the cam **35** as may be caused by slowly reciprocating the forming tube and collet axially during the fiber forming run. With each axial movement of the collet with respect to the cam **35**, a separate layer is wound on the forming tube so that the ultimate package has a plurality of parallel layers **42** of strand wound in superposed relation on the forming tube **28**. Each succeeding layer is of shorter length than the preceding layer and the end of each succeeding layer terminates short of the end of each preceding layer.

The winder, including the cam **35** and collet **29** and means for providing the reciprocatory movement between the two, is generally indicated at **45** in FIGS. 1 and 2. The winder **45** is shown in greater detail in FIGS. 3 and 4. It is composed of a base **47** and a sheet metal framing enclosure **49** mounted on the base. A carriage **50** is mounted on the base on a pair of slides **52** which are mounted on supports **53** rigidly fastened to the base.

Accordion-like sleeves 55 are attached to the supports 53 and carriage 50 so as to protect the lubricated slides 52 from any dirt or other foreign substances.

The supports 53 act as mechanical stops for the reciprocating straight-line motion of the carriage 50 on slides 52. The carriage is reciprocated by means of a piston rod 57 which is rigidly attached to the carriage 50 at 58 and whose pistons 60 and 61 are mounted respectively in an oil cylinder 63 and air cylinder 64 mounted in tandem. The oil cylinder serves as a dashpot for smoothing out the movement of the pistons 60 and 61 caused by alternating air pressures on opposite sides of piston 61 in the air cylinder 64. Air is supplied to opposite ends of the cylinder 64 by lines 65 and 66 which are connected to a four-way, two position, bleeder-actuated, balanced, air valve 68. The details of the valve 68 and its method of controlling the air flow to the cylinder are discussed in further detail in conjunction with the description of the operation of the winder. The oil in the cylinder 63 passes from one side of the piston 60 to the other side by means of line 67 connected to each end of the cylinder 63.

The drive for the collet 29 is motor 70 which is adjustably mounted on the carriage 50. The collet 29 is mounted on a spindle 72 which is supported in a cylindrical bearing for rotation but limited to movement in an axial direction on an upright portion 75 of the carriage 50. The spindle 72 is rotated by means of a belt 78 which is connected to and driven by the motor 70. The motor 70 is equipped so direct current can be applied to the motor windings to reduce its speed.

The structure of the cam 35 has been discussed above with respect to FIGS. 1 and 2 and its mounting and drive are now discussed in detail with respect to its showing in FIGS. 3 and 4. A plate 84 is rigidly attached to an upright support 85 mounted on base 47, and the plate 84 serves as a support for the cam 35 and its motor drive 86. The motor 86 is rigidly fastened to and supported on the plate 84 and the cam 35 extends through two hollow, cylindrical bearings in projections 88 extending downwardly from the plate 84. A pair of guides 90 mounted on the cam 35 prevent axial movement of the cam 35 in the bearings. The alignment of the cam 35 is such that the axis of the cam is parallel to the axis of the collet spindle 72. The cam 35 is slightly above and to one side of the collet 29. The cam 35 is driven by means of a belt 92 which is connected to and driven by the motor 86. The cam 35 rotates but does not move axially as does the collet 29.

The cam 35 is mounted so that its groove 38 is in a vertical plane with the guide 32 and the center of the bushing 18, said plane being perpendicular to the axes of the cam 35 and the collet 29. The guide 32 is located directly under the center of the bushing 18 but the axis of the cam groove 38 is offset in the aforementioned vertical plane approximately 10 to 15 degrees from a vertical line drawn through the center of the bushing and the guide 32. This angle is just slightly larger than the angle formed by the outside or end filaments with the vertical line. The collet 29 and forming tube 28 are mounted below the guide 32. The strand 30 passes over the cam 35 under slight tension as it moves between the guide 32 and the forming tube 28. As shown in FIG. 1, the cam 35 intercepts an imaginary line drawn from the guide 32 to the point on the periphery of the forming tube 28 where the strand first contacts the tube. This position is required so that the cam 35 is able to positively engage the strand and move it back and forth as it is wound upon the forming tube.

The operation of the winder 45 during the glass fiber forming process can best be described in conjunction with the description of the schematic drawing of the electrical system in FIG. 5 and the schematic drawing of the pneumatic system in FIG. 6. In starting the fiber forming process the operator pulls the strand 30 across the guide 32 and wraps it around the end of the collet 29 extending beyond the forming tube 28. The collet 29 is at its innermost position at the start of the run. While doing this, the operator has his foot on a foot switch 100 having normally closed contacts FS–1 and FS–3 and normally open contact FS–2 located in a 120 volt alternating current circuit generally designated 102 in FIG. 5.

Contacts FS–1 and FS–2 are in a circuit in series with a normally closed push-button switch PB–1, the primary winding P of a transformer 104, normally closed contact 2M–1 and a coil 1CR of a relay having normally open contacts 1CR–1, 1CR–2, 1CR–3, 1CR–4 and 1CR–5. The winding P and contact 2M–1 are in parallel with each other. A normally closed contact 3TR–1 is in another circuit in parallel with contact FS–1 and in series with push-button PB–1, contact FS–2, normally closed contact 4TR–1, normally open contact 1CR–1, primary winding P, contact 2M–1 and coil 1CR. The contacts 4TR–1 and 1CR–1 are in series with each other and in parallel with contact FS–2. The various contacts PB–1, FS–1, FS–2, 3TR–1, 1CR–1, 2M–1 and 4TR–1 together with primary winding P form in combination with coil 1CR a plurality of circuits through which coil 1CR can be energized or deenergized.

Depression of the foot switch 100 by the operator as he starts the winding process opens contacts FS–1 and FS–3 and closed contact FS–2. Current is then able to flow through the circuit containing contacts PB–1, FS–2, 3TR–1, 2M–1 and coil 1CR to energize the coil 1CR and close the normally open contacts 1CR–1 and 1CR–2. When contact 1CR–1 is closed a holding circuit is completed having in series contacts PB–1, 4TR–1, 1CR–1, 3TR–1, 2M–1 and coil 1CR to maintain coil 1CR energized upon release of the foot switch 100.

Release of the foot switch 100 closes contacts FS–1 and FS–3. Contact FS–3 is located in another circuit in series with normally open, now closed, contact 1CR–2, normally closed contact BC–1 and coil 1M of a starter for the collet motor 70. This energizes coil 1M of the starter and starts the collet 70. Coil 1M has normally closed contacts 1M–2 and 1M–4 and normally open contacts 1M–1 and 1M–3. When coil 1M is energized, interlock contact 1M–3 is closed in another circuit to energize a collet oscillating timer 1TR and a collet motor braking timer 2TR in parallel with each other and in series with contact 1M–3. The timer 1TR, of the on delay type, is set, e.g., for about 4 to 6 seconds to permit the collet motor 70 to attain sufficient speed to rotate the collet at about 7,650 r.p.m. When 1TR times out, its normally open contact 1TR–1 closes. The contact 1TR–1 is in series with normally open contact 1CR–3, now closed, and with a solenoid SV–1 of a normally closed, spring biased, solenoid valve 105, timer 3TR of the on delay type and solenoid SV–2 of a normally open solenoid valve 106 in line 67 connected to the oil cylinder 63. The solenoids SV–1 and SV–2 and coil 3TR are in parallel with each other. The solenoid valve 105 controls the oscillation of the collet. The timer 3TR, through its normally open contact 3TR–2 of the on delay type, initiates the rotation of the cam 35. The solenoid valve 106 allows slow reciprocation of the collet when it is closed and permits a rapid return of the collet to the home or starting position at the end of the run when it is open.

Energizing of the solenoid SV–1 by closing contact 1TR–1 opens the solenoid valve 105. This opens a portion of the pneumatic system for controlling the oscillation of the collet 29 and permits the collet to move outward from its home position. Also, when contact 1TR–1 closes, the timer 3TR is energized. The timer 3TR times out and closes the normally open contact 3TR–2 which is in series in another circuit with the coil 2M of the starter for the cam motor 86. The closing of contact 3TR–2 (after a delay of about 1 to 3 seconds) starts the rotation of the cam 35. With this arrangement the cam

35 does not begin to rotate until after the collet comes up to speed and has moved outwardly from the innermost or home position in response to the energization of the solenoid SV–1.

At the same time that the cam motor 86 is started, a synchronous motor timer 4TR is energized. The timer 4TR is in parallel with coil 2M and in series with contact 3TR–2. The timer 4TR is set for the length of the run, for example 10 minutes. At the end of the run timer 4TR times out to close its normally open contact 4TR–2 so that a light L in series with contact 4TR–2 in another circuit is lit to indicate to the operator that the run is complete.

Normally closed contact 4TR–1 in series with the 1CR holding circuit described above times open at the end of the run and since contact FS–2 is open, the coil 1CR is deenergized. When coil 1CR is deenergized, its contact 1CR–2 is opened, but this does not deenergize collet motor starter 1M and stop the collet motor because the holding circuit containing limit switch LS–2 and normally open, now closed, contact 1M–1 continues to energize the starter 1M.

When coil 1CR is deenergized, its contact 1CR–3 is opened, solenoid SV–1 closes and solenoid SV–2 opens to cause the carriage 50 to return rapidly to its innermost position. The solenoid SV–2 opens line 67 to permit oil in cylinder 63 to move rapidly from one side of piston 60 to the other and permit rapid return of the carriage to its home position. When timer 3TR is deenergized, its contacts 3TR–2 are opened and cam motor 86 is stopped. Contacts 3TR–1, which opened after a delay of about 3 seconds when timer 3TR was initially energized is closed when timer 3TR is deenergized and this permits coil 1CR to be energized when the foot switch 100 is depressed.

When the carriage returns to the innermost position, limit switch LS–2 is opened and the holding circuit for the starter 1M is broken. This deenergizes starter 1M which disconnects collet motor 70 from its power lines and closes contacts 1M–2. With the closing of contacts 1M–2, the collet motor brake contactor BC is energized. This applies direct current to the motor windings which dynamically brakes the motor to bring it quickly to a stop. The deenergizing of starter 1M also opens contact 1M–3 which in turn deenergizes timers 1TR and 2TR.

When 2TR was initially energized contact 2TR–1 in series with normally closed contact 1M–2 and brake contactor BC was instantaneously closed; however, since 1M–2 was open the brake contactor was not energized. When 2TR is deenergized as just described above, its contacts 2TR–1 will remain closed for approximately six seconds to allow sufficient time for the collet motor to be stopped, Thereafter it will open and the brake contactor is deenergized to remove the direct current from the motor.

If for some reason it is desired to stop the winder before the normal length of time set for a run, the operator can depress the foot switch 100 to open contact FS–1. Since contact 3TR–1 is also open, the coil 1CR is deenergized, the winder returns to its innermost position and starter 1M is deenergized. The winder may be restarted as described by release of the foot switch if the foot switch is held depressed until the winder returns to its home position and starter 1M is deenergized.

The winder is automatically stopped if the strand breaks. When the strand 30 is passing over the spring loaded guide 32, the tension of the strand moves the guide against a normally open limit switch LS–1 to close a circuit containing the limit switch LS–1 and the secondary winding S of the transformer. When limit switch LS–1 is closed thereby short circuiting the secondary winding S of the transformer a small impedance is reflected to the primary winding P of the transformer. In this situation, there is only a small voltage drop, i.e., 20 volts, across the primary winding and there is sufficient voltage left in the circuit in which the primary winding P is located to maintain coil 1CR energized. When the strand breaks, the pressure on the guide 32 is released and limit switch LS–1 is opened. The secondary winding of the transformer is opened and this reflects a very high impedance to the primary winding P of the transformer. This produces a high voltage drop across the primary winding P and there is insufficient voltage left in the circuit in which the primary winding P is located to maintain the coil 1CR energized. The coil 1CR becomes deenergized because of this and because contact 2M–1 is open while the cam motor 86 is running. The normally closed contact 2M–1 permits bypassing of the transformer circuit during the start-up of the winder. The transformer is used with limit switch LS–1 so that switch LS–1 is in a low voltage circuit and the operator will not be subjected to a high voltage line in case he touches the circuit in which the limit switch is located.

The pneumatic system is shown schematically in FIG. 6. Air valve 68 as previously mentioned controls the air supplied to each side of the piston 61 mounted in air cylinder 64. The air valve 68 is of the balanced type, for example, as shown in United States Patent No. 2,607,197. The air valve 68 is composed of a casing 110 providing a chamber 112 to which air under high pressure is constantly supplied through an inlet port 113 connected by pipe 114 to an air pressure source. A spool or plunger 115 is mounted within the chamber 112 for movement lengthwise of the chamber. The spool 115 is provided with pistons 117 and 118 at each end which in combination with the walls of the chamber 112 act to separate the chamber into three sections, a central section 119 into which the air under pressure is continuously provided, and sections 120 and 121 at the ends of the chamber. The central section of the chamber is connected to the end sections 120 and 121 by small ports 122 and 123 in the pistons 117 and 118 to provide for eventual equalization of the pressure in the three sections of the chamber. This permits the spool 115 to be in a balanced position within the chamber 112. The spool is moved lengthwise in the chamber by exhausting the air from either end sections 120 or 121 to temporarily unbalance the air pressure within the sections of the chamber and cause the spool to move toward the end of the valve from which the air has been exhausted.

One wall of the central portion of the chamber 112 provides a seat 124 for a slide valve 12 connected with the spool and normally urged by spring 126 against the seat. The inlet port 113 is located beyond the range of movement of the slide valve 125 so that air under pressure is constantly supplied to the chamber 112. The casing 110 has three passage opening into it through the wall forming the valve seat 124. Two of the passages 127 and 128 are connected respectively by lines 65 and 66 to opposite ends of the air cylinder 64. The third passage 130 is connected by a suitable line 131 to the atmosphere through muffler 132 and serves as an exhaust. In one position of the slide valve 125, the passage 127 communicates with the central section 119 of the chamber and it causes air under pressure to be directed toward one side of the piston 61 in air cylinder 64. In this position the passage 128 is connected through valve 125 and passage 130 to the atmosphere and thus serves as an exhaust for the air from the other side of the piston 61 in air cylinder 64. In the other position of the slide valve 125, the passage 128 communicates with the central section 119 of the chamber 112 and the passage 127 communicates with the atmosphere through valve 125 and passage 130.

The sliding of valve 125 is accomplished by alternately bleeding air from the end sections 120 and 121. This is accomplished by means of poppet valves 133 and 134 which are connected to end sections 120 and 121 respectively through air lines 135 and 136 connected to passages in the end walls of the casing 110.

The poppet valves 133 and 134 are mounted on the base

47 of the winder 45 in a line parallel to the travel of the carriage 50 and the collet 29. An automatically adjustable poppet valve engaging means 140 is rigidly attached to the side of the carriage 50 and as the carriage moves back and forth, the engaging means 140 alternately contacts the poppet valves to open them and cause the end sections 120 and 121 of the chamber 112 of valve 68 to be exhausted alternately to the atmosphere. The oil cylinder 63 connected to the air cylinder 64 causes the movement of the carriage to be smooth rather than abrupt. The cylinder 63 contains oil and this oil bleeds through an opening 141 in the piston 60 mounted on the piston rod 57 which extends through the oil cylinder to the air cylinder, and on which piston 61 is also mounted.

The extent of movement of carriage 50 is determined by the engagement of the means 140 alternately with the poppet valves 133 and 134. The engaging means 140 shown in greater detail in FIGS. 7, 8 and 9, is composed of racks 143 and 144 which engage poppet valves 133 and 134 respectively. The effective lengths of the racks 143 and 144 is determined by pinion 147. When the pinion rotates counter-clockwise as viewed in FIG. 7, the rack 143 is caused to move to the left and thereby increase its effective length as a cam for engaging poppet valve 133 and rack 144 is caused to move to the right and thereby increase its effective length as a cam for engaging poppet valve 134. The racks 143 and 144 move respectively in channels 150 and 151 in support 153 which is rigidly attached to the side of the carriage 50.

The pinion 147 is mounted on an axle 155 which is mounted for rotation in bearings in the support 153. The pinion 147 is driven by means of a ratchet 160 which is also mounted on axle 155 and the ratchet 160 is in turn given rotational movement by means of pawl 162. The pawl 162 is caused to move by movement of the carriage 50. As the carriage moves to the left as shown in FIG. 7, roller 165 comes into contact with stationary cam 170 mounted on the base 47. The roller 165 is mounted for free rotation on the end of link 172 which is pivotally mounted at 173 on support 153. The link 172 is normally held in an upright position by means of spring 175 attached at one end to fixed pin 176 extending from support 153 and at the other end to the end of the link 172 opposite from the roller.

Engagement of the roller 165 with the cam 170 causes the link 172 to rotate. This in turn causes link 180 to move. Link 180 is connected at one end to a pin 182 mounted on link 172 between the pivotal mounting of the link and the end of the link containing the roller 165 and mounted at the other end to the central portion of a link 183. Link 183 is mounted for free rotation at one end on a bearing integral with the axle 155 and carrying on its other end pawl 162 which is spring biased thereon to hold the pawl in engagement with the teeth of the ratchet 160. Another pawl 185 is pivotally mounted on pin 186 extending from support 153 and is spring loaded so that the engaging end of the pawl is held in position against the teeth of the ratchet 160. The pawl 185 serves to hold the ratchet in its new position each time the pawl 162 returns to its original position when the carriage moves to the right and the roller 165 becomes disengaged with the cam 170. Thus, for each movement of the carriage to the left and return the ratchet is moved one notch and the racks 143 and 144 are moved outwardly a short distance, for example, 1/16 to 1/4 inch.

The operation of the winder with respect to the oscillation of the carriage 50 and collet 29 is now described. The solenoid valve 105 controls the operation of air valve 68 to control whether or not the carriage 50 returns to and remains in its innermost starting position or whether it oscillates between positioned spaced outwardly from the innermost starting position. When the solenoid valve 105 is closed, the line 136 connecting passage 138 to poppet valve 134 is closed and no air can escape from end section 121 whether the poppet valve 134 is open or not. If the carriage 50 is in its innermost position and the solenoid valve 105 is closed, the carriage will stay in that position. When the carriage is in the innermost position, the rack 144 holds the poppet valve 134 open; however, the carriage 50 cannot move forward until the solenoid valve 105 is open so as to connect the end section 121 with the poppet valve 134 through line 136. The various valves and pistons in the pneumatic system are shown in FIG. 6 in their position at start-up with the piston 61 in the cylinder 64 being in the first or innermost position indicated adjacent the cylinder 64.

As established in the above description of the electrical diagram in FIG. 5, the collet starts to rotate and the strand initially formed is wound at the end of the collet for a time interval until the collet gets up to the desired winding speed. After this interval, the normally open contact 1TR–1 closes to energize solenoid SV–1 of the solenoid valve 105. The solenoid valve 105 opens and exhaust line 136 is now open to poppet valve 134. The balanced condition of air valve 68 is upset and the spool 115 and slide valve 125 move to reverse the flow of air through lines 65 and 66 to the cylinder 64 and cause the piston 61 and carriage 50 to move forward.

As the carriage 50 approaches its outermost position, the rack 143 engages poppet valve 133 to exhaust air through line 135 from end section 120 of chamber 112 and unbalance the valve 68. The spool 115 and slide valve 125 are moved to their alternate positions and the flow of air in lines 65 and 66 to the cylinder 64 is again reversed to stop the carriage at the outermost position and reverse its movement. A similar procedure is followed when the rack 144 engages poppet valve 134 on the return motion of the carriage and the carriage is stopped and reversed at a third position intermediate the first (innermost) and second (outermost) positions.

The balancing and unbalancing of the air valve 68 causes the carriage 50 and collet 29 to move automatically slowly back and forth through distances as determined by the engagement of the racks 143 and 144 with the poppet valves 133 and 134 respectively. Since the racks are extended with each movement of the carriage back and forth on the base, they strike the poppet valves 133 and 134 sooner with each pass than in the preceding pass. This results in each succeeding layer of strand wound on the forming package terminating slightly inwardly in an axial direction from the end of the preceding layer. The buildup of the layers 190 of strand is shown in FIG. 10.

FIG. 10 is an elevation partly in section showing diagrammatically how a strand, such as a 400 filament, 150 strand, is built up in superposed layers 190 on the forming tube 28. Each layer 190 is deposited in the form of a filling wind with the strand being laid down with a very slight traverse from cam 35 and with the layer being first formed at one end of the tube and progressing slowly to the other end by virtue of the relatively slow axial movement of the collet with respect to the cam 35. The strand is wound around the forming tube in small helixes so that generally each turn of the strand is parallel to the preceding turn with the exception that the strand describes a very flat sine wave, i.e., 1 to 10 degrees at the point of crossover, as imposed by the low amplitude, high frequency action of cam 35. The axial movement of the collet is slow enough with respect to the rotation of the collet that the strand is deposited upon itself in each layer to a thickness of about 4 to 8 strand diameters.

The movement of the collet causes the leading edge of the layer A to be built up at an angle α to the surface of the forming tube, i.e., about 10 to 20 degrees as measured in a plane parallel to and containing the axis of the collet. At the end of a layer this angle α is steeper as the collet pauses prior to starting on the return trip. As the strand transfers from one layer (A) to the next (B), it passes several times around the tube in first the end of layer A

and then in the beginning of the next layer B. As the collet starts back in the opposite direction, the leading edge of the next layer (B) is sloped in the opposite direction at the same angle β to the surface of the forming tube as the preceding layer. Each layer at the end where the last strand is laid down as contrasted to the end where the new layer begins terminates short of the end of the preceding layer.

As stated in the objects of the invention, it is desired that the diameter of the fibers in the strand formed in each of the succeeding layers **190** in the forming package be the same. tI can be seen that in forming package **192** each succeeding layer increases the diameter of the package and thus increases the attenuating speed of the fibers if the r.p.m. of the collet is maintained constant. As stated above this increase in diameter in the forming package can be compensated for by increasing the temperature of the bushing during the fiber forming run and/or reducing the r.p.m. of the collet. Both of these methods will be discussed.

In FIGS. 11 and 12 a means for increasing the bushing temperature stepwise with the formation of each layer is shown. This means is described in conjunction with FIG. 7. Mounted on the base **47** are two limit switches **203** and **204**. These limit switches are mounted in line with the poppet valves **133** and **134** with limit switch **203** being mounted on the base just inboard of poppet valve **133** so that rack **143** strikes the limit switch **203** shortly before it strikes the poppet valve **133** and with limit switch **204** being mounted on the base just inboard of poppet valve **134** so that rack **144** strikes the limit switch **204** just before it strikes the poppet valve **134**. The limit switches **203** and **204** are located in suitable circuits for either changing the bushing temperature or the r.p.m. of the collet motor.

FIGS. 11 and 12 show circuits for increasing the bushing temperature and the fluidity of the molten glass after the completion of each longitudinal movement of the carriage so that each succeeding layer on the forming package will be wound at the same effective attenuating speed so as to produce the same diameter fiber. An electrical power circuit containing suitable controls for supplying energy to the bushing **18** is shown in FIG. 11. The power circuit includes a saturable core reactor **206** in series with a power transformer **208** for the bushing **18**. The bushing terminals **24** connect the bushing **18** in series with the secondary winding **210** of the transformer **208**. The primary winding **212** of the transformer **208** is connected in series with the saturable core reactor **206** and the series circuit is connected through contacts **213** of a line circuit breaker to a suitable power line source, L_3, L_4, such for example as a 440 volt, 60 cycle line.

The current regulating controls for the power circuit may be provided by a conventional temperature measuring and regulating unit **215** which is arranged to operate in conjunction with a thermocouple **216** which is in thermal contact with the bushing **18**. The unit **215** measures the temperature of the bushing **18** by means of the thermocouple **216** and indicates the temperature signal at a meter **217** provided with means for presetting the temperature desired. As the temperature signal fed to the unit **215** varies from a preset value, the unit functions to supply a corrected signal to the power circuit by way of the saturable reactor to establish the heating current flow to the bushing for the temperature desired.

The unit **215** receives in addition to the signal from the thermocouple **216** an auxiliary signal from a variable resistance unit **218** which in effect causes a false signal to be supplied to the temperature regulating unit **215**. The increase in temperature of the bushing is accomplished by supplying a false temperature signal to the temperature regulating unit **215** from the variable resistance unit **218** along with the actual temperature signal supplied by the thermocouple **216**. The variable resistance unit **218** is connected to the regulating unit **215** in series with the thermocouple **216** and is so arranged that an increase in the signal from the unit **218** causes a decrease in the total signal so as to indicate falsely to the temperature regulating unit **215** that the temperature of the bushing **18** is falling. The temperature regulator unit **215** then sends an increased current signal to the saturable core reactor which reduces the inductive reactance of the reactor and permits more current to be supplied to the transformer **208** and consequently more current to the bushing **18**.

The variable resistance unit **218** is shown in FIG. 12 in more detail in combination with the temperature regulating unit **215**, thermocouple **216** and bushing **18**. Electrical energy for the false signal generated by the resistance unit **218** is supplied over suitable power lines of an alternating current source L_5, L_6. This energy is supplied to a rectifier **220** which provides a constant direct current reference voltage for the false signal circuit. The direct current portion of the variable resistance unit circuit contains rheostats **222**, **224** and **226** from the positive side of the rectifier. Rheostat **222** is used to control the current supplied to potentiometer connected rheostat **224** and rheostat **226** is used to control the rate of temperature change. The rheostat **224** is mechanically changed by a spring biased ratchet **230** which is driven by pawl **232** in stepwise fashion so as to derive a variable voltage which can be used to pass current through a resistance **233** which is in series with the thermocouple **216** and temperature regulating unit **215**.

The pawl **232** is spring loaded so as to be normally out of contact with ratchet **230**. The pawl **232** is actuated by coil **234** to move against the teeth of ratchet **230** to rotate it. The coil **234** is in series with limit switches **203** and **204** (which are in parallel with each other) and with normally open contact **2M–2**. Contact **2M–2** is closed as solenoid valve **105** is opened and the collet begins to move out from the home position. Thereafter, each time either of the limit switches is closed by racks **143** and **144**, the pawl **232** steps up ratchet **230** and the rheostat **224** is changed stepwise for each axial movement of the collet. A spring biased pawl **236** is normally engaged with ratchet **230** to keep the ratchet from returning to its original position as pawl **232** retracts each time. The pawl **236** is disengaged from the ratchet by coil **240** which is in series with normally open contact **BC–2**. Contact **BC–2** is normally open but is closed when brake contactor **BC** is energized to stop the collet motor **70**. When contact **BC–2** is closed, coil **240** is energized, pawl **236** is retracted and ratchet **230** returns to its original position. Ratchet **230** is ready for another fiber-forming run when coil **240** is deenergized and pawl **236** again engages the ratchet.

The circuit just described produces a stepwise varied current through a low value resistance **233** connected in series with the bushing thermocouple. The current flowing through the resistance **233** produces the false temperature supplied to the temperature regulating unit.

In FIG. 13 there is shown a diagrammatic view of an electrical control means for varying the speed of the collet motor while maintaining the bushing temperature constant in order to compensate for the increase in diameter of the forming package. This is an alternative to the control means shown in FIGS. 11 and 12. In the control means shown in FIG. 13 there is a reference signal generating unit which supplies a speed command signal to a conventional adjustable speed drive power and control unit which in turn controls the speed of the collet motor. The speed of the motor is modified by the power and control unit to be directly proportional to the reference signal. The reference signal generating unit is adjusted to produce a signal and determines the speed of the collet motor at the beginning of the fiber forming run. This signal is decreased stepwise during the run in response to the limit switches **203** and **204**.

A direct current reference source **250** produces a con-

stant voltage from power lines L_7, L_8. The reference voltage causes a current to flow through a voltage divider network composed of rheostats **252** and **254** and pawl driven potentiometer rheostat **256** in series with each other. A rheostat **258** is in parallel with rheostat **256** and in series with rheostats **252** and **254**. Rheostats **252** and **254** are positioned in tandem with a common adjustment shaft so that as the resistance of one is increased, the resistance of the other is decreased, and vice versa, so that their total resistance remains constant. These rheostats fix the speed of the motor at the beginning of the run. Rheostat **258** controls the extent to which the speed of the collet can be reduced during the run. Rheostat **256** controls the actual speed of the motor and is driven by a ratchet and pawl arrangement (not shown) in combination with limit switches **203** and **204** in the same manner as described above with respect to ratchet **230** and pawls **232** and **240** in FIG. 12.

The speed reference signal between the brush contact of the rheostat **256** and the negative reference source line is compared to the speed feed-back signal from a tachometer generator **260** that is driven from the collet motor **70** and the difference or error signal is fed to a conventional adjustable speed drive power unit **262** to control the speed of the motor.

The winder as described automatically produces a forming package composed of a continuous strand of substantially uniform diameter from the beginning of the forming package to the end of the package. The end of the strand can be easily found at that point in the outermost layer of strand where the fiber forming operation ended. The strand can be unwound over end from the forming package without undue creation of fuzz or strand breakage.

The above description of the invention and the details of its operation are intended to be exemplary and not limiting upon the scope of the invention except as set forth in the accompanying claims.

I claim:

1. A method of forming a glass fiber strand which comprises drawing a plurality of individual glass filaments from a supply of molten glass, combining the filaments into a strand, winding the strand on a rotating cylindrical support in superimposed parallel layers, terminating each layer short of each preceding layer as the layers are formed so that each succeeding layer is shorter in length than the preceding layer, rotating the support at a constant angular velocity during the fiber forming process, and increasing the fluidity of the molten glass being drawn into fibers after the end of each layer is completed and before the next succeeding layer is begun and in response to the length of each said layer.

2. The method as described in claim **1** in which the fluidity of the glass is increased by increasing its temperature after the end of each layer is completed and before the next succeeding layer is begun.

3. A method of forming a glass fiber strand which comprises drawing a plurality of individual glass filaments from a supply of molten glass, combining the filaments into a strand, winding the strand on a rotating cylindrical support in superimposed parallel layers, terminating each layer short of each preceding layer as the layers are formed so that each succeeding layer is shorter in length than the preceding layer, and reducing the angular velocity of rotation of the support after the end of each layer is completed and before the next succeeding layer is begun and in response to the length of each said layer.

4. Apparatus for forming a strand of glass fibers which comprises a container for holding a supply of molten glass and means for drawing a plurality of glass fibers from the container including a guide for grouping the fibers into a strand, a cylindrical support onto which the strand is wound in a plurality of superimposed layers, means for rotating the support, means for providing reciprocating relative motion between the guide and support in a direction parallel to the axis of the support, means for progressively shortening the distance of the reciprocatory motion during the winding process so that each layer terminates short of each preceding layer and each succeeding layer is shorter in length than the preceding layer, and means for increasing the fluidity of the glass being attenuated during the winding process after the end of each layer is completed and before winding the next succeeding layer in response with the formation of each said layer.

5. Apparatus for forming a strand of glass fibers which comprises a container for holding a supply of molten glass and means for drawing a plurality of glass fibers from the container including a guide for grouping the fibers into a strand, a cylindrical support onto which the strand is wound in a plurality of superimposed layers, means for rotating the support, means for providing reciprocating relative motion between the guide and support in a direction parallel to the axis of the support, means for progressively shortening the distance of the reciprocatory motion during the winding process so that each layer terminates short of each preceding layer and each succeeding layer is shorter in length than the preceding layer, and means for decreasing the angular velocity of the cylindrical support during the winding process after the end of each said layer is completed and before the next succeeding layer is begun.

6. Apparatus for forming a strand of glass fibers which comprises a container for holding a supply of molten glass and means for drawing a plurality of glass fibers from the container including a guide for grouping the fibers into a strand, a cylindrical support onto which the strand is wound in a plurality of superimposed layers, means for rotating the support, means for providing reciprocating relative motion between the guide and support in a direction parallel to the axis of the support, means for progressively shortening the distance of the reciprocatory motion during the winding process so that each layer terminates short of each preceding layer and each succeeding layer is shorter in length than the preceding layer, and means for increasing the fluidity of the glass being attenuated during the winding process stepwise after the end of each layer is completed and before the next succeeding layer is begun.

7. Apparatus for forming a strand of glass fibers which comprises a container for holding a supply of molten glass and means for drawing a plurality of glass fibers from the container including a guide for grouping the fibers into a strand, a cylindrical support onto which the strand is wound in a plurality of superimposed layers, means for rotating the support, means for reciprocating the support relative to the guide in a direction parallel to the axis of the support, means for progressively shortening the distance of the reciprocatory motion during the winding process so that each layer terminates short of each preceding layer and each succeeding layer is shorter in length than the preceding layer, and means actuated by said last-named means for increasing the fluidity of the glass being attenuated during the winding process after the end of each layer is completed and before the next succeeding layer is begun.

8. Apparatus for winding a strand on a forming tube in a plurality of superimposed layers and being formed from fibers drawn from molten glass comprising a rotatable collet for receiving the forming tube onto which the strand is wound, a support for said collet, traversing means rotatable about a fixed axis and in a fixed location for traversing said strand onto said tube, means to reciprocate said collet and its support along and through a predetermined path relative to said traversing means at a substantially uniform speed, means to successively change the direction of movement of said collet and its support, means to control the length of said path and to change said length as the strand is wound onto said

tube, said control means including means reciprocable with said support means to activate said direction changing means and means to change the length of said reciprocable means and thus the length of the path of reciprocation of said collet and its support, said reciprocable means including a pair of toothed racks and said length changing means including a pinion meshing with said racks and being rotatable through determined increments upon reciprocation of said support, and means actuated by said reciprocable means for increasing the fluidity of the molten glass after the end of each layer is completed and before the next succeeding layer is begun.

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