May 16, 1939. A. FORMHALS 2,158,416

METHOD AND APPARATUS FOR THE PRODUCTION OF ARTIFICIAL FIBERS

Filed July 28, 1937 3 Sheets-Sheet 1

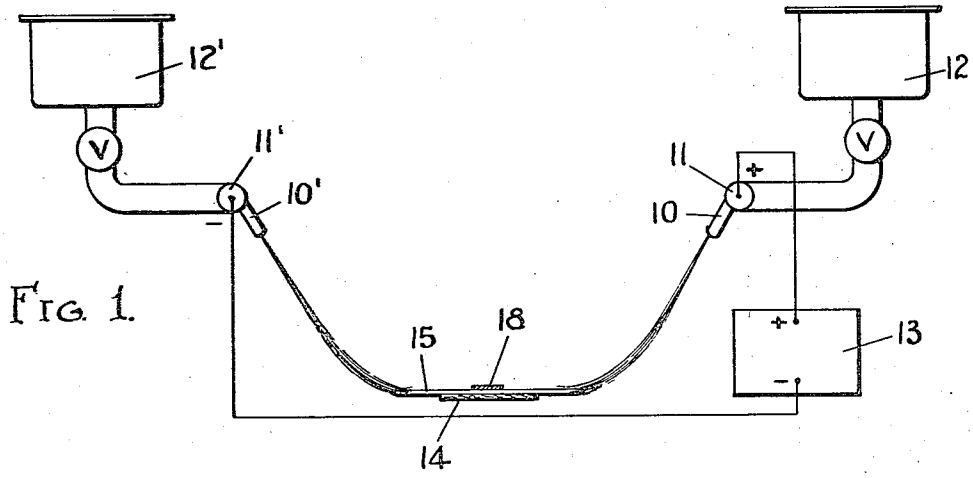

FIG. 1.

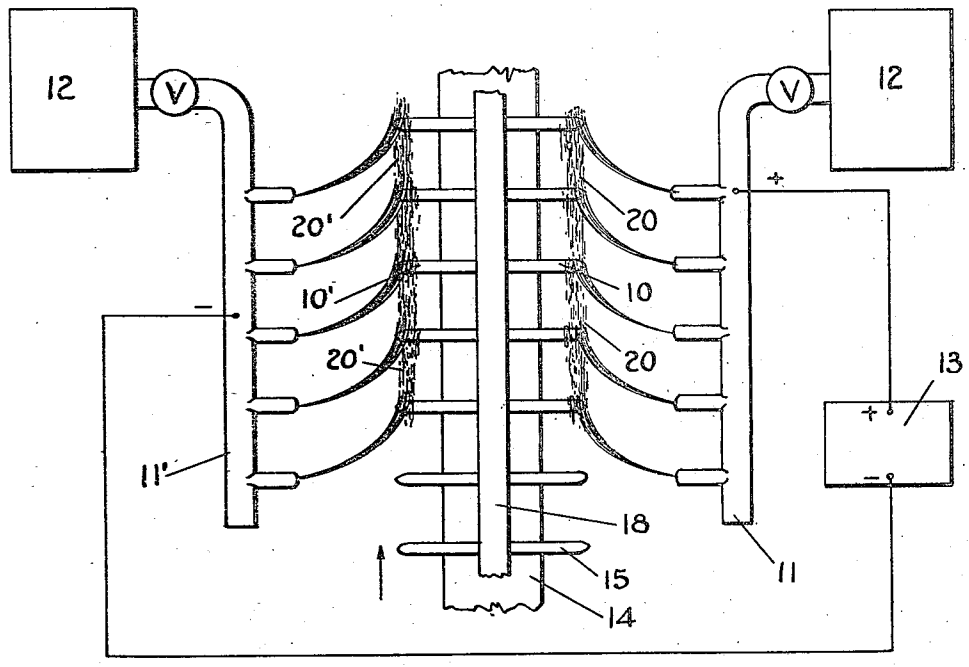

FIG. 2.

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METHOD AND APPARATUS FOR THE PRODUCTION OF ARTIFICIAL FIBERS

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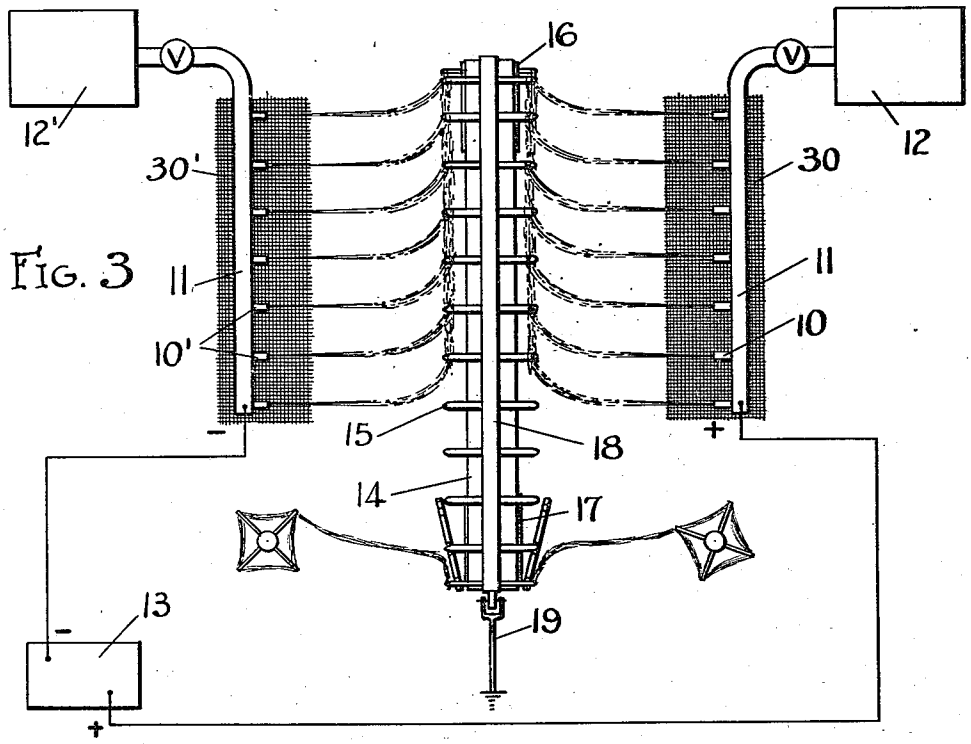

FIG. 3

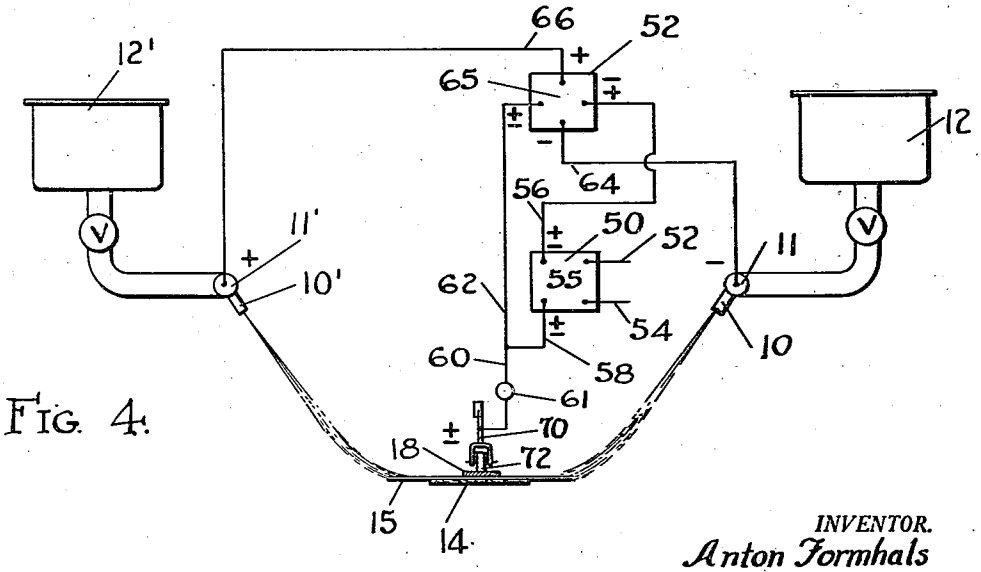

FIG. 4.

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METHOD AND APPARATUS FOR THE PRODUCTION OF ARTIFICIAL FIBERS

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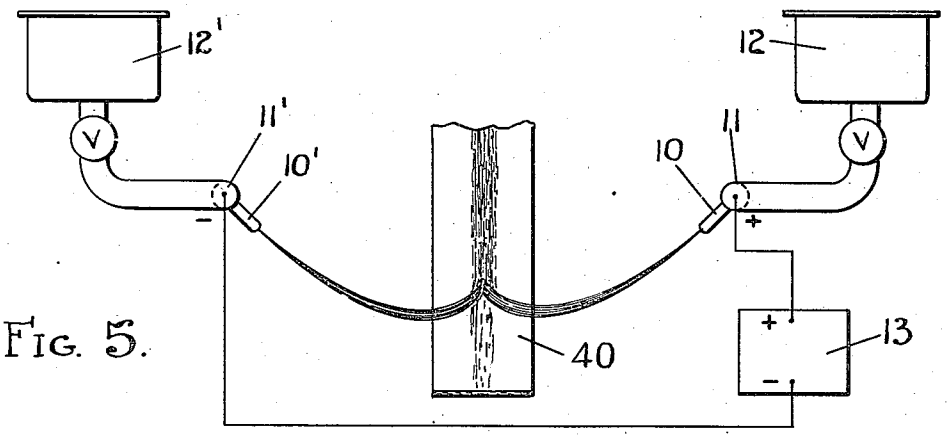

FIG. 5.

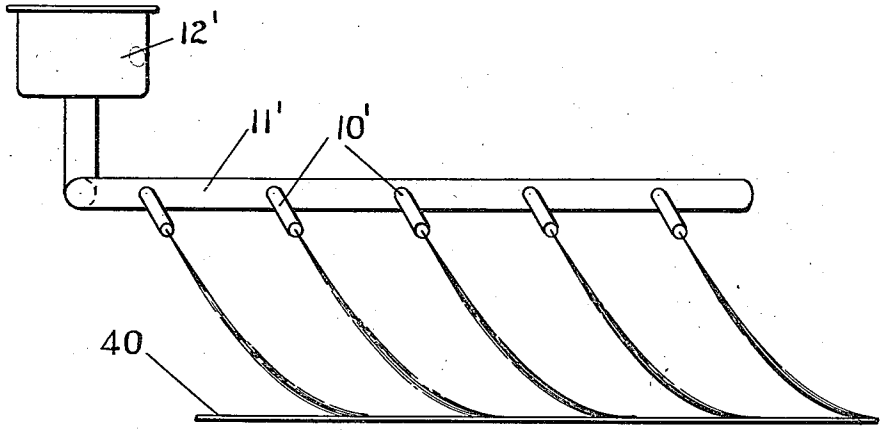

FIG. 6.

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Patented May 16, 1939

2,158,416

UNITED STATES PATENT OFFICE

2,158,416

METHOD AND APPARATUS FOR THE PRODUCTION OF ARTIFICIAL FIBERS

Anton Formhals, Mainz, Germany, assignor of forty-five one-hundredths to Richard Schreiber-Gastell, Mainz, Germany

Application July 28, 1937, Serial No. 156,169

11 Claims. (Cl. 18—8)

This invention relates to the production of artificial fibers, and more particularly, relates to a new process and apparatus for electrically spinning artificial fibers. By "electrical spinning" is meant the dispersion or shattering of a stream of spinning solution by means of a high electrical potential.

It has been disclosed in Formhals U. S. Patent No. 1,975,504 that solutions of filament-forming materials may be spun into fibers by causing the spinning solution, in the form of a stream, to be extruded between two electrodes bearing electrical charges of high potential and opposite polarity; one of the electrodes being the spinning jet, and the other electrode comprising a moving collector for the fibers. The high potential electric charge on the spinning jet is apparently transmitted to the spinning solution and causes the same to be shattered or dispersed to produce a multiplicity of charged fibers or filaments which are attracted to and collected on the moving electrode.

Some difficulty is experienced in this method of electrical spinning from the annoying tendency of certain stray fibers to become electrostatically charged with a charge of the same polarity as the collecting electrode as it approaches the same, whereby the fibers tend to travel back into the electrical field surrounding the solution feeding device. For example, a fiber leaving the spinning jet may be charged negatively, but as it approaches the field of the collecting electrode, the fiber may become positively charged from the collecting electrode before it reaches the latter. In this case the positively charged collecting electrode will repel the positively charged fiber which, as a result, never reaches the collector. In some cases the fibers may temporarily adhere to the collecting electrode, but due to the high electrical potential thereon, are repelled and thrown back to the jet electrode. Other fibers, after reaching the collecting electrode and partially adhering thereto, are positively charged and the ends thereof which have not had an adequate opportunity to attach themselves to the collecting electrode are projected outwardly at an angle to the collecting electrode and generally give a sliver having poor characteristics. The stray fibers which happen to fly back into the proximity of the jet electrode tend to become attracted and attached to various parts of the jet electrode. The fibers may thus accumulate around the spinning jet electrode to a sufficient extent to cause serious interference to the free and continuous delivery of the spinning solution.

In copending application to Anton Formhals, Serial No. 88,431, filed July 1, 1936, the difficulty due to stray fibers is overcome to a large extent by maintaining the electrical potential of the collecting electrode substantially lower than the electrical potential on the spinning jet electrode. This lower potential on the collecting electrode is secured, for example, by means of an air gap placed between the source of the electrical potential and the collecting electrode. Such a procedure is a decided improvement over that of Formhals U. S. Patent No. 1,975,504, but has still the disadvantage that the collecting device is charged and therefore dangerous from the standpoint of fire hazard and the safety of the operator. In addition, the air gap has to be frequently adjusted since the charge on the collecting electrode varies with such factors as the type of solution being spun, the temperature and humidity of the air, the distance between the collecting electrode and the spinning jet electrode, and the total electrical potential between the two electrodes. Moreover, if the air gap is too large between the source of the electrical potential and the collecting electrode, one is faced with the disadvantage of the fibers overshooting the collecting electrode with resultant waste from the fibers flying about the spinning room.

It is therefore one object of the present invention to provide an electrical spinning process wherein good collection of the fibers is secured primarily by the position of the collecting device with respect to the spinning jet electrodes rather than by the amount of electrostatic potential on the collecting device.

Another object of the present invention is to devise a novel process for the electrical spinning of fibers.

Still another object of the invention is to overcome the difficulty due to stray fibers in the electrical spinning of fibers.

Specifically, the object of the invention is to electrically spin fibers from oppositely charged sets of jet electrodes, the said sets being placed on opposite sides of a moving collecting device.

Accordingly the invention embraces a process comprising electrically spinning a spinning solution from sets of jet electrodes, each set having preferably a substantially equal but opposite electrical charge from that on the other, collecting the oppositely charged fibers on a moving collecting device that is placed in the electrically

neutral area between the oppositely charged, relatively symmetrical electrical fields.

By the term "electrically neutral area" we refer to the area of zero potential between oppositely charged electrical fields.

By the term "non-electrode" as applied to the collecting device, is meant a collecting device which is not charged with a high electrical potential and which, therefore, may be touched by an operator without danger.

In the preferred embodiment of the invention, the spinning solution is extruded from two sets of spinning jet electrodes, each set bearing a high electrical potential of equal and opposite charge, and the charged fibers are collected in the form of a sliver on the tips of a plurality of metallic prongs fastened to a belt which may be constructed of rubber, leather, canvas, cambric or other suitable material. The belt with its prongs is preferably grounded and so positioned with respect to the two sets of spinning jet electrodes that it moves through the electrically neutral area between the two oppositely charged electrical fields. Each of the two sets of spinning jet electrodes is regulated to deliver substantially the same amount of spinning solution.

In order to more clearly set forth the present invention, reference is made to the following detailed description taken in connection with the accompanying illustration, in which:

Figure 1 is an end elevational view, partially in section, showing the oppositely charged spinning jets and the collecting device of an apparatus constructed in accordance with this invention.

Figure 2 is a top plan view of the apparatus shown in Figure 1;

Figure 3 is a top plan view of an electrical spinning apparatus including a means for grounding the collecting device;

Figure 4 is an end elevational view, partially in section, showing a modified form of electrical spinning device;

Figure 5 is a diagrammatic illustration of a modified form of the invention;

Figure 6 is a side elevational view of the apparatus shown in Figure 5.

Referring to the drawings, a spinning solution from storage tanks 12 and 12' is supplied to a plurality of metal spinning jets 10 and 10', which are connected respectively to the pipes 11 and 11'. The spinning jets 10 and 10' and pipes 11 and 11' are charged with a high electrical potential of equal and opposite charge by being electrically connected to opposite poles of a device 13 for producing high potential electric current. Device 13 may be a transformer and rotary convertor for changing ordinary line current, such as 110 volt-60 cycle, alternating electric current, into a high voltage, pulsating, electric current, or 13 may be any suitable device for producing a high potential direct current. For obtaining special effects in the shattering of a stream of spinning solution, 13 may be a suitable device for producing an alternating current of high potential of any desired or varying frequency.

Spaced equidistant from the two sets of spinning jet electrodes 10 and 10' is a long, endless belt 14 preferably comprising rubber or any other suitable, non-conductive material, although an electrically conducting material such as metal may be used. The belt is provided with spaced metal prongs or lugs 15 which are fastened to the belt so as to project from both sides thereof. The prongs 15, which are preferably pointed at their ends projecting from the sides of the belt, are disposed substantially within the plane of the belt, with the projecting ends extending perpendicularly from the side of said belt. The belt is driven by pulleys 16 and 17 which are preferably composed of wood or some other suitable, electrically non-conducting material. The oppositely charged sets of jet electrodes 10 and 10' are positioned a distance apart at least equal to and preferably more than the distance between the jet electrodes and the collecting device, and far enough apart to prevent sparks jumping across between the sets of jet electrodes and creating a fire hazard. The collecting belt is positioned at such a distance from the electrodes that the spinning solution will be well dispersed or shattered into separate filaments before they contact with the prongs 15. The belt is furthermore positioned somewhat lower than the spinning jets and with the points of the prongs projecting from one side of the belt spaced at substantially an equal distance from jets 10 as the oppositely projecting ends of the prongs are spaced from jets 10'. In this manner, the fibers produced from the solution flowing from jets 10 will collect on the ends of the prongs projecting from one side of the belt and the fibers from the solutions issuing from the opposing set of jets are collected on the opposite ends of the prongs in the form of continuous slivers 20 and 20'. The electrical charges on the fibers collecting on one side of the belt are opposite to those collecting on the other side and will neutralize each other to maintain the belt collector substantially neutral.

In the preferred embodiment of the invention, an electrically conductive element 18 is positioned on the collector belt to electrically connect the individual prongs 15 to each other. An electrically grounding mechanism 19 can be contacted with the element 18 so as to prevent the presence of an electrical charge on the prongs or belt in case the belt is inadvertently forced closer to one set of spinning jets than to the other set. The grounding mechanism may comprise a trolley with the trolley wheel having continuous rolling contact with the element 18. It is to be understood, however, that the apparatus will be operative without the element 18 and the grounding mechanism.

The electrical potential on the jet electrodes between the sets of jet electrodes may be varied between 10,000 and 100,000 volts and preferably is maintained at a potential of at least 30,000 volts. Since the resistance from the device 13 to the sets of jet electrodes is equal and since there is no leakage of the voltage, the potential charge on each set of electrodes is substantially equal and opposite in charge.

Potential stabilizing and directing means 30 and 30', comprising, for example concavely curved metallic screens or strips are preferably positioned in back of the jet electrodes 10 and 10'. The means 30 and 30' are connected to a charge of high electrical potential of the same polarity as the potential on the corresponding sets of jet electrodes. The directing means serve to direct the charged fibers towards the prongs of the belt and to overcome any difference in symmetry of the electrical field surrounding the jet electrodes.

The potential stabilizing and directing means is the subject of my copending application Serial No. 88,430, filed July 1, 1936, and reference is made to the said application for details thereof.

The following detailed example of one embodiment of a process for carrying out the present

invention is given as a specific illustration and is not to be considered as limiting the scope of the invention.

Example

A solution having a viscosity at 25° C. of 35.7 poises and consisting of 150 grams of cellulose acetate, 600 grams of acetone and 300 grams of the monomethyl ether of ethylene glycol is forced through two opposing sets of single hole jet electrodes, the orifice diameters of which are approximately 0.0180 inch. Opposite poles of a source of pulsating, direct current of 50,000 volts are connected to opposing sets of jet electrodes. The streams of cellulose acetate solution are broken under the influence of the high electrical potential existing between the charged jets and a moving collecting belt into numerous fine filaments which are deposited on and carried away by the prongs of the moving belt. The charged fibers from one set of jet electrodes, upon deposition, apparently impart a charge to the opposite tip of the metal prong upon which are attracted, collected and neutralized the oppositely charged fibers from the other set of jet electrodes. The net result is that the belt remains substantially electrically neutral and two essentially uncharged slivers are collected on the tips of the prongs. To insure that the streams of solution and the fibers produced therefrom are properly directed to the prongs, the belt is placed in the electrically neutral area between the electrical fields surrounding the oppositely charged sets of jet electrodes and below the electrode jets at a distance which essentially represents a balance between gravity and electrical forces exerted on the solution and the fibers. The fibers may additionally be directed upon the prongs by means of metallic screens positioned back of the jet electrodes and possessing an electrical charge of the same sign as that of the electrode. During the dispersion or shattering of the stream of solution and deposition of the fibers, the solvent evaporates, the fibers quickly drying as they are carried away from the spinning zone. The fibers are thus oriented in a position substantially parallel to the direction of travel of the belt and due to their rapid drying and substantial freedom from electrostatic charge, adhere neither to the prongs nor to one another, to any objectionable degree. The continuous sliver thus formed is removed by a stripping device and deposited in a suitable container or wound on a reel. Prior to drawing or twisting, and preferably prior to winding the sliver, it is treated with a suitable textile finish in a fashion similar to the treatment of wool rovings so as to facilitate the ease and smoothness of drawing. The sliver treated with a suitable textile finish is drawn and/or twisted to yield a yarn of any weight desired.

In another form of the present invention the oppositely charged sets of jet electrodes are positioned relatively close together and at a considerable distance from any ground, such as the belt mentioned hereinbefore. As a result, the oppositely charged fibers sufficiently attract one another and as they come in contact they neutralize the charge on each other. The neutralized fibers fall by gravity and preferably are collected continuously in the form of a sliver-like bundle on a collector, for example, an endless belt. This mode of operating the invention also offers an excellent procedure for producing staple in a fluffed form.

Referring to Figures 5 and 6 of the invention, the spinning solution is extruded from oppositely charged sets of spinning jet electrodes 10 and 10', each set consisting, for example, of 20, 50, 100 or more jet electrodes. The spinning solutions are electrically dispersed into fibers which are attracted to each other along a line intermediate the sets of spinning jets. As the fibers contact each other, they become neutralized and fall to the belt 40 and are carried away to a container or wind-up device. If desired, the fluffed staple fibers may be permitted to fall by gravity to the floor and then removed by suction, by a stream of air or fluid, or by a belt or other mechanical means. The fluffed staple may be converted into a sliver by the usual textile operations.

Referring to the modification of the invention illustrated in Figure 4 of the drawings, reference numeral 50 designates a source of high potential alternating current such as a transformer in which low potential alternating current such as 110–120 volt 60 cycle current is transformed to 10,000 to 100,000 volt 60 cycle current. Lead wires 52 and 54 connect to a source of low voltage alternating line current and to the low voltage side of the transformer 55. Lead wires 56 and 58 are connected between the high voltage terminals of the transformer 55 and the alternating current poles of rotary converter 65. Lead wires 64 and 66 are connected between the direct current poles of rotary converter 65 and to the pipe lines 11 and 11' respectively. A lead wire 60 is connected to lead wire 58 (or 56) and to trolley 70. The wheel 72 of the trolley contacts the element 18 which connects the various prongs 15 or belt 14. In this modification, it may be desired to place an air gap or other resistance designated by 61 in lead 60. The function and utility of such an air gap or resistance is specifically disclosed in my copending application Serial No. 88,431, filed July 1, 1936.

In operation the prongs will be alternately charged with a positive and negative high potential in accordance with the frequency of the alternating current. The prongs 15 will therefore have an alternate attraction and repulsion for the fibers. Inasmuch as the frequency of the alternation is a small fraction of a second, it will not prevent the adherence of the fibers to the prongs for the formation of a sliver thereon. The alternations, however, have the desirable function of giving a curliness or crimp to the fibers since they are alternately attracted and repelled before the solvent has been evaporated therefrom and while they are still in a plastic state.

The modification shown in Figure 4, therefore, does not have some of the desirable features of the other modifications in which the belt and prongs carry no dangerous high potential charge of electricity, but has certain other advantages not possessed by the previously described modifications. The various modifications are all common to each other, however, in that they have opposing sets of jet electrodes connected to opposite poles of a source of a high electrical potential.

While the rate of delivery of the spinning solution from the sets of jet electrodes may be varied with respect to one another within a limited range, still it is preferred for most satisfactory operation that the rate of delivery be substantially the same from each set of jet electrodes. Likewise, while preferred, it is not absolutely necessary to have the potential equal on the oppositely charged sets of electrode jets, some

difference in potential being overcome by the use of directing means, such as the electrically charged screen mentioned hereinbefore, or a current of air. The collecting device, however, is preferably placed in the neutral zone between the electrodes even though in cases where the sets of jets have unequal potentials it will necessitate positioning of the collecting device nearer one set than the other set.

The present invention may also be advantageously applied to the spinning of solutions of cellulose acetate in solvents other than acetone or the monomethyl ether of ethylene glycol. Certain solvents in the spinning solution will cause a greater or lesser shattering of the liquid stream than others and some solutions will require a higher potential than others for the satisfactory breaking up of the stream and the formation of fibers. Solutions of other cellulose esters, for instance cellulose propionate, cellulose aceto-propionate, cellulose aceto-butyrate, cellulose aceto-stearate and solutions of cellulose ethers such as ethyl or benzyl cellulose may also be spun by the procedure of the invention. Generally, solutions of resins, molten glass or other materials which may be formed into fibers may also be spun in accordance with the method of the invention. It has been found that polymerized resins of alkyl esters of acrylic acids, and specifically polymerized methyl methacrylate resin, can be electrically spun to produce particularly desirable fibers. These acrylic acid resins may be dissolved in suitable solvents, such as acetone together with a suitable plasticizer if desired and electrically dispersed or shattered in the same manner as the spinning solutions above described.

The moving collecting device which may or may not be grounded, on which the fibers are collected in a continuous sliver, may be driven at any desired speed to obtain varying effects. However, when it is desired to collect the fibers in a compact, coherent sliver, in which the fibers are arranged substantially parallel to each other, it is essential that the linear speed of the collecting device be at least as high as, and preferably higher than the speed of the freshly formed fibers in their travel towards the collecting device. It is preferred that the collecting device be a continuance belt with prongs. However, it may comprise any other form of collecting device such as a wheel, in which case one sliver is continuously formed. Or, the collector may be some other device provided, like the belt, with prongs around its circumference, which prongs are adapted to mesh with a suitable means for removing the sliver from the collection device. If desired, suitably positioned air jets may be used to remove the sliver or may be used in conjunction with various mechanical devices in removing the sliver from the collecting mechanism.

Suitable delustering agents such as pigments, oils, organic solids and similar materials may be introduced into the spinning solution to produce delustered, semi-lustrous and other effects. Likewise, dyed filaments or fibers may be spun by introducing suitable dyes or other coloring matter into the solution.

The process of the invention as illustrated in Figures 1, 2, 3 and 5 offers greater ease in controlling the uniformity of the electrical spinning operation in that it utilizes a collecting device that is not an electrode in the sense that the collecting device is not connected to an electrical potential, either directly or through an air gap. As a result, the operating conditions may be varied over a wider range than in previous methods since inherently the procedure is not affected so critically by factors such as humidity and temperature, the distance between the jet electrodes and the collecting device, and the fluctuations in electrical potential, and changes in the electrical potential. Since there is no high electrical potential wire relatively close to the collecting device, the danger of operators suffering from electrical shock or from explosions due to electrical sparking in the presence of solvent vapors is practically eliminated.

The process of the invention as illustrated in Figure 4 has the advantage of forming a sliver composed of very curly or highly crimped fibers which more nearly simulate wool.

Economically, the process of the invention in accordance with all of the modifications affords a relatively cheap and efficient mode of electrically spinning and collecting fibers and also utilizes floor space efficiently.

It will be obvious that many changes and modifications can be made in the above described apparatus and processes without departing from the nature and spirit of the invention. It is therefore to be understood the invention is not to be limited except as set forth in the appended claims.

I claim:

1. In an apparatus for the electrical spinning of fibers a set of spinning jet electrodes, a second set of spinning jet electrodes spaced from said first set, means for connecting said sets of jet electrodes to opposite poles of a source of high electrical potential, a moving collecting means positioned substantially in the neutral zone intermediate said sets of jet electrodes for collecting fibers from both of said sets of jet electrodes, the space between said sets of jet electrodes being sufficiently great to prevent the passing of a spark therebetween due to their opposite charges of electricity and being sufficiently small to cause an attraction to each other of the oppositely charged fibers spun from the said jet electrodes.

2. In an apparatus for the electrical spinning of fibers a set of spinning jet electrodes, a second set of spinning jet electrodes spaced from said first set, means for connecting said sets of jet electrodes to opposite poles of a source of high electrical potential, a moving collecting means positioned below and substantially in the neutral zone intermediate said sets of jet electrodes, the space between said sets of jet electrodes being sufficiently great to prevent the passing of a spark therebetween due to their opposite charges of electricity and being sufficiently small to cause an attraction to the collecting means of the oppositely charged fibers spun from the said jet electrodes.

3. In an apparatus for the electrical spinning of fibers a set of spinning jet electrodes, a second set of spinning jet electrodes spaced from said first set, means for connecting said sets of jet electrodes to opposite poles of a source of high electrical potential, a moving collecting means having prongs projecting from opposite sides thereof positioned below and substantially in the neutral zone intermediate said sets of jet electrodes, the space between said sets of jet electrodes being sufficiently great to prevent the passing of a spark therebetween due to their opposite charges of electricity and being sufficiently small to cause an attraction of the fibers

spun from one set of electrodes to the prongs projecting from one side of the collecting means and an attraction of the fibers spun from the other set of electrodes to the prongs projecting from the other side of the collecting means.

4. In an apparatus for the electrical spinning of fibers as defined in claim 1, means connected to said collecting device to maintain the same electrically grounded.

5. In an apparatus for the electrical spinning of fibers as defined in claim 3, means connected to said prongs to maintain the same electrically grounded.

6. In an apparatus for the electrical spinning of fibers as defined in claim 3, means connected to said prongs to alternately impart thereto a high potential of opposite sign.

7. In a process for the electrical spinning of fibers, the step which comprises imparting a high electrical potential of opposite sign to spaced streams of spinning solution whereby to cause them to be electrically shattered into fibers, and collecting said fibers on a collecting means common to said spaced streams.

8. In a process for the electrical spinning of fibers, the steps comprising extruding a plurality of streams of spinning solution from one zone, extruding a second plurality of streams of spinning solution from a second zone, imparting high electrical potentials of opposite sign to the streams of spinning solution in said two zones respectively, said zones being separated a distance sufficient to prevent electrical sparks being created therebetween but which will permit the resulting spun fibers to be attracted to each other, and collecting said fibers on a collecting means common to said plurality of streams.

9. In a process for the electrical spinning of fibers, the steps comprising extruding a plurality of streams of spinning solution from one zone, extruding a second plurality of streams of spinning solution from a second zone, imparting high electrical potentials of opposite sign to the streams of spinning solution in said two zones respectively, said zones being separated a distance sufficient to prevent electrical sparks being created therebetween, and collecting the fibers from said two zones on opposite sides of a collecting device positioned therebetween to form two independent slivers of fibers.

10. In a process for the electrical spinning of fibers, the steps comprising extruding a plurality of streams of spinning solution from one zone, extruding a second plurality of streams of spinning solution from a second zone, imparting high electrical potentials of opposite sign to the streams of spinning solution in said two zones respectively, said zones being separated a distance sufficient to prevent electrical sparks being created therebetween, and collecting the fibers from said two zones on opposite sides of a collecting device positioned in an electrically neutral zone therebetween to form two independent slivers of fibers.

11. In a process for the electrical spinning of fibers, the steps comprising extruding a plurality of streams of spinning solution from one zone, extruding a second plurality of streams of spinning solution from a second zone, imparting high electrical potentials of opposite sign to the streams of spinning solution in said two zones respectively, said zones being separated a distance sufficient to prevent electrical sparks being created therebetween but which will permit the resulting spun fibers to be attracted to each other, and collecting said fibers in the form of a single sliver substantially in a neutral zone intermediate said extruding zones.

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