

June 11, 1968

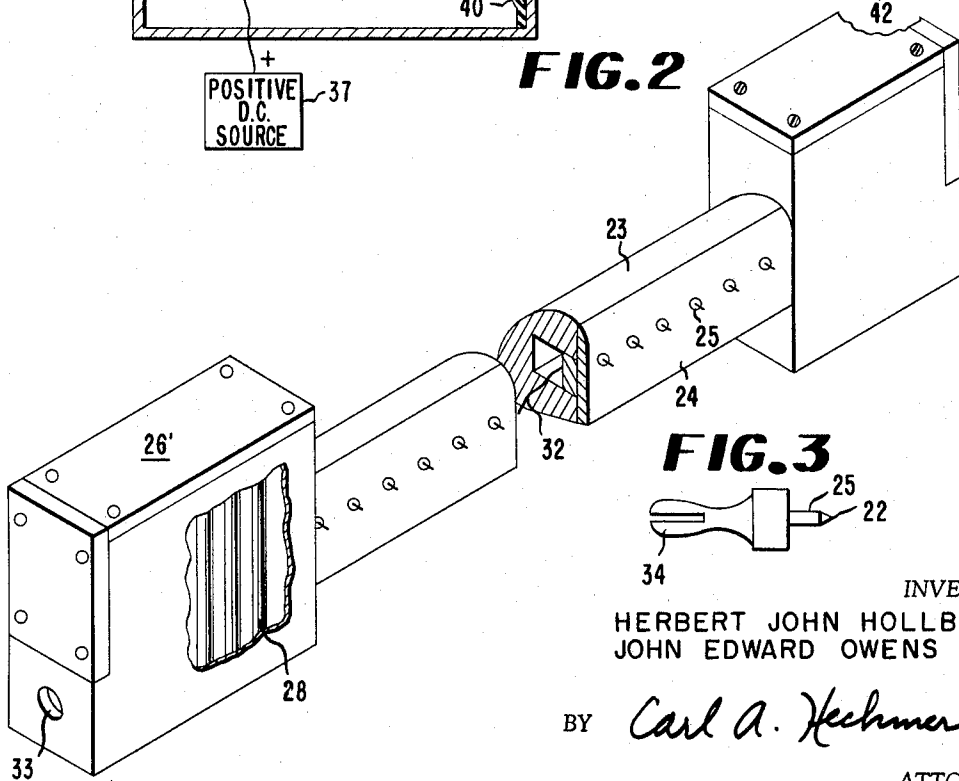
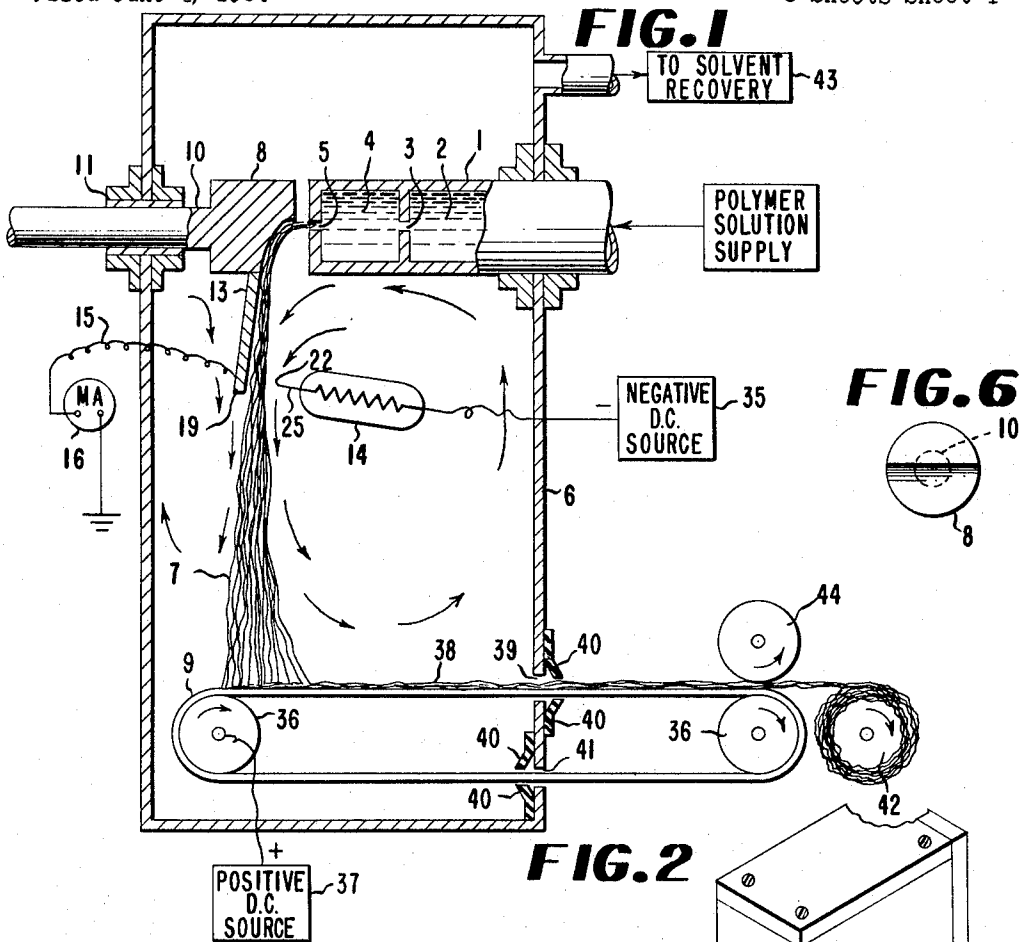
H. J. HOLLBERG ETAL

3,387,326

APPARATUS FOR CHARGING AND SPREADING A WEB

Filed June 4, 1964

3 Sheets-Sheet 1



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APPARATUS FOR CHARGING AND SPREADING A WEB

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FIG. 4

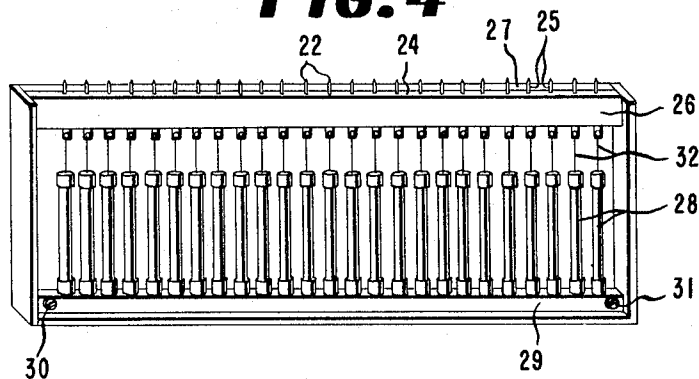


FIG. 5

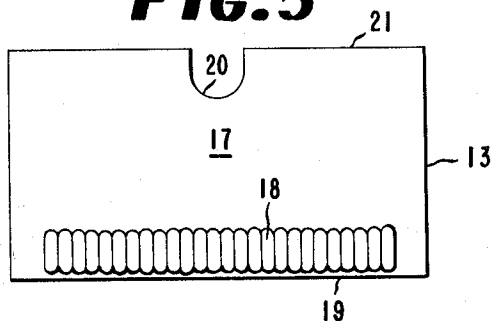


FIG. 8

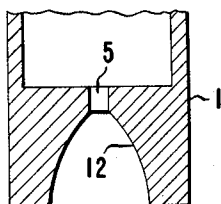
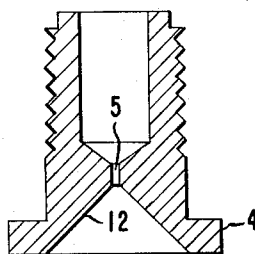


FIG. 9



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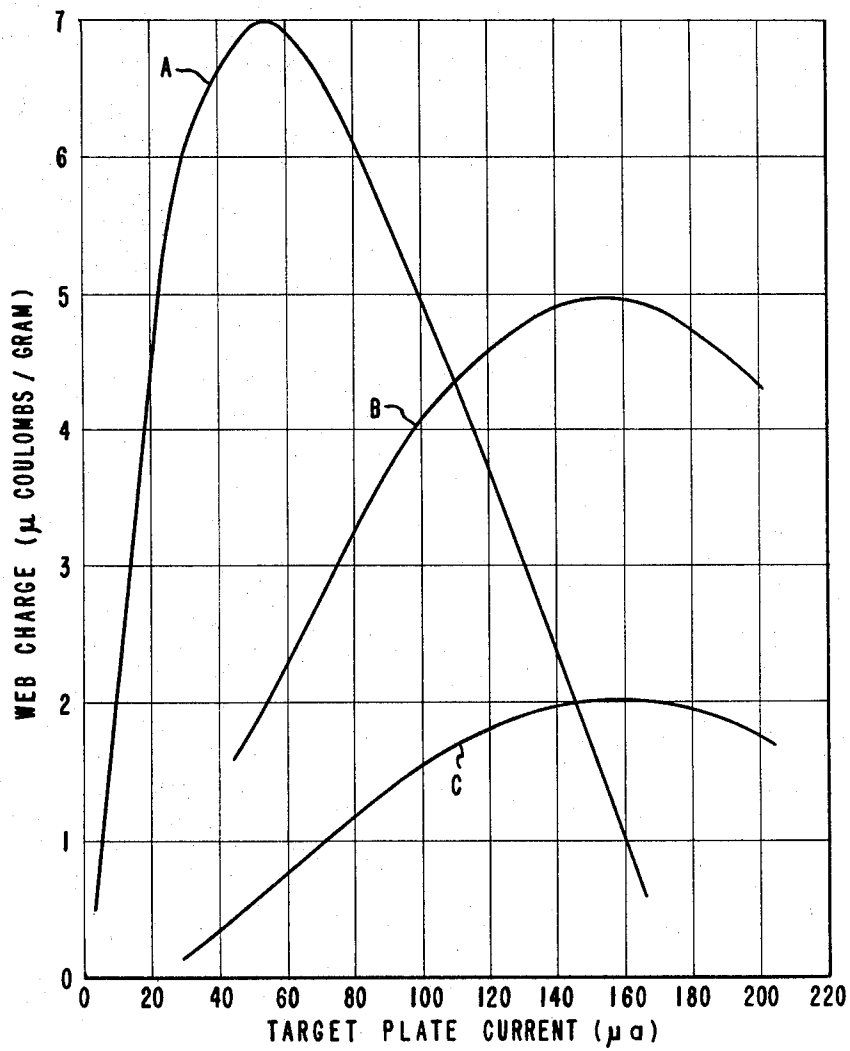
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APPARATUS FOR CHARGING AND SPREADING A WEB

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3 Sheets-Sheet 3

FIG. 7



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3,387,326 APPARATUS FOR CHARGING AND SPREADING A WEB

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3 Claims. (Cl. 18-8)

ABSTRACT OF THE DISCLOSURE

An apparatus for spreading, electrostatically charging, and forwarding a fibrous web concomitantly formed with a vapor blast. The apparatus includes a spinning means for forming and directing the web to a baffle which serves to spread the web and direct it to a corona charging device located downstream from the baffle.

This invention concerns a novel and useful apparatus for charging fibrous webs in an electrostatic field and depositing the webs uniformly in overlapping layers on a moving surface to form a nonwoven sheet.

The apparatus described and claimed herein is particularly useful in charging webs of a continuous fibrillated strand described in U.S. Patent 3,081,519 to Blades and White. This web is prepared by flash extrusion of a solution of crystallizable polymer. In the "flash extrusion" process the strand is formed by extruding a homogeneous solution of a fiber-forming polymer dissolved in a liquid which is a solvent for the polymer above its normal boiling point. The solution, at a temperature above the normal boiling point of the solvent and at autogenous or greater pressure, is extruded into a medium of lower temperature and substantially lower pressure. The vaporizing liquid within the extrudate forms bubbles, breaks through confining walls, and cools the extrudate, causing solidification of the polymer. The resulting fibrous web is a multifibrous yarn-like strand having an internal fine structure or morphology which may be characterized as a 3-dimensional integral plexus consisting of a multitude of essentially longitudinally extended, interconnecting, random-length fibrous filaments, hereafter referred to as film-fibrils. These film-fibrils have the form of thin ribbons with an average thickness less than about 4 microns. The film-fibril elements often found as aggregates, intermittently unite and separate at irregular intervals called "tie-points" in various places throughout the width, length, and thickness of the strand to form an integral 3-dimensional plexus. The film-fibrils are often rolled or folded about the principal film-fibril axis, giving the appearance of a fibrous material when examined without magnification. The strand comprising a 3-dimensional network of film-fibril elements is referred to as a plexifilament. The plexifilaments are unitary, i.e. the strands are one continuous piece of polymer, and the elements which constitute the strand are interconnected. They can be produced in essentially endless lengths in deniers as low as 15 or as high as 100,000 or even higher.

The plexifilamentary web may be spread out by causing it to impinge on a baffle or curved surface as it exits from the extrusion orifice. It may then be deposited upon a moving belt in overlapping, multidirectional layers to form a nonwoven fibrous sheet. Prior art apparatus for this purpose is described in Belgian Patents 625,998 and 621,943. The apparatus of the present invention permits formation of a much more uniform product than can be obtained with that previously known, particularly when forming sheets from plexifilamentary webs which contain superfine fibrils that otherwise would tend to form ropy strands.

It is an object of the present invention to provide improved apparatus for charging fibrous webs in an electrostatic field. Another object is to provide a highly uniform, nonwoven fibrous sheet from a plexifilamentary. These and other objects will become apparent in the course of the following specification and claims.

In accordance with the present invention apparatus is provided for separating and electrostatically charging a fibrous web such as a plexifilamentary web and forwarding it for deposit on a moving surface to form a nonwoven sheet. This apparatus includes a means to supply a fibrous web in an axial path of advance and a means for providing a vapor blast for guiding and controlling the web along the path. The extrusion device commonly used in plexifilamentary formation provides each of these elements, the vapor blast originating at a spinneret orifice by vaporization of solvent as it enters an atmosphere of lower pressure. A spreading means, such as a baffle, preferably capable of oscillation, to be impinged by the web and the vapor, the gas expansion on the baffle being sufficient to cause separation of the various fibers in the web is provided in the path of advance. A corona charging device is provided along the path of advance just downstream from the mechanical spreading device. It serves to place a charge on the fibers in the web and to thereby sustain them in a separated or opened condition. The charging device includes an electrode, i.e. an ion gun and a second electrode, i.e. a target plate. The target plate is placed immediately adjacent to the mechanical spreading means in such manner that the vapor blast from the spinneret guides the web to provide brushing contact with the target. The target plate is of flat plate construction assembled in the equipment with the flat surface facing the ion gun and the path of advance. The trailing edge of the target plate terminates in an essentially straight, thin edge to provide uniform but minimum aerodynamic turbulence at this point during operation. The ion gun is a structure supporting a row of charging needles disposed transverse to and across the path of advance. The gun is placed opposite the target and mounted in a manner that permits circulation of vapor around it, since during operation the confined gases tend to flow toward the path of advance over the top of the gun. Preferably the face and the top of the gun housing are smooth and shaped to minimize aerodynamic turbulence. The needles are aimed at points near the trailing edge of the target plate determined by a technique described hereinafter. The spread and charged fibrous web is then deposited on a continuously moving surface, electrically discharged and collected by conventional means such as windup in a roll. Preferably sufficient of the equipment is enclosed to permit recovery of the vapor when desirable.

The process of the invention described in terms of sheet production from plexifilamentary webs comprises the following steps:

Flash extruding a solution of organic polymeric material into a gaseous atmosphere to form a plexifilamentary strand or web, mechanically spreading the strand or web, passing the spread web through a substantially planar ion cloud wherein the initiating electric potential provides a charge on the web between 75 and 100% of the peak charge with the target plate current less than that which produces peak charge, depositing the web on a moving collecting surface on which is imposed a charge opposite to that on the web to provide a strong electrostatic attraction between the collecting surface and the depositing web thereby consolidating the collected sheet and pinning it to the collecting surface.

The invention will be more readily understood by reference to the drawings.

FIGURE 1 is a cross sectional elevation indicating

schematically the arrangement of the various elements of the apparatus of the present invention.

FIGURE 2 is a perspective view partially in section of an ion gun useful in the apparatus of the present invention.

FIGURE 3 is an elevation of the plug-in corona discharge needle of the ion gun of FIGURE 2.

FIGURE 4 is a top view with the top cover removed of a second embodiment of an ion gun suitable for use in the device of the present invention.

FIGURE 5 is a front elevation of the target plate of FIGURE 1.

FIGURE 6 is a front elevation of the baffle of FIGURE 1.

FIGURE 7 is a series of curves wherein web charge is plotted as ordinate versus target plate current as abscissa.

FIGURES 8 and 9 illustrate "shrouded" spinning orifices useful in mechanically separating the plexifilament as it is spun.

Referring particularly to FIGURE 1, a spinneret device 1, connected to a source of polymer dissolved in an organic solvent is shown. Polymer solution 2 under pressure is fed through extrusion orifice 3 into intermediate pressure or "let-down" pressure zone 4 and then through spinning orifice 5 into web forming chamber 6. The extrudate from spinning orifice 5 is a plexifilament 7. Due to the pressure drop at spinning orifice 5 vaporization of solvent creates a vapor blast which, by virtue of impingement upon baffle 8 concomitantly with plexifilament 7, generally follows the path of advance of the plexifilament 7 from spinning orifice 5 to collecting surface 9, thereby creating a flow pattern within chamber 6 as indicated by the arrows. Baffle 8 is mounted on shaft 10 which in turn is oscillatably mounted in bearing 11 and is powered to oscillate by means not shown. While oscillation of the baffle is not essential, it is preferred for the preparation of wide sheets. The baffle described and claimed in U.S. application filed on or about May 29, 1964 in the name of Herbert John Hollberg is particularly useful. Alternative mechanical spreading arrangements are illustrated in FIGURES 8 and 9 where spinning orifice 5 of spinneret device 1 is surrounded at its extrusion face with a shroud 12, FIGURE 8 illustrating a bell-shaped shroud and FIGURE 9 a conical shroud. The plexifilament on extrusion tends to open and follow the contours of the shroud. The extrudate can be impinged upon a fixed or moving baffle or directed along the path of advance without baffling when the shrouded orifice is employed to spread the web.

As shown in FIGURE 1 a target plate 13 and an ion gun 14 are disposed on opposite sides of the path of advance of the plexifilament web, downstream from the web forming and mechanical separating devices. Target plate 13 is so disposed that the vapor blast originating at 5 and the air flow pattern in chamber 6 carries plexifilament 7 along its charging surface. Target plate 13 is connected to ground by wire 15 and microammeter 16 which indicates target plate current. FIGURE 5 is a front elevation of target plate 13. Charging surface 17 is shown with an indicating carbon deposit 18 near its trailing edge 19 and a semi-circular cut-out 20 along its leading edge 21. Cut out 20 accommodates the periphery of baffle 8, a front elevation being illustrated in FIGURE 6. While the placement of the baffle within the leading edge of the target plate is not essential, such an arrangement helps to avoid collection of polymeric material on the top edge of the target plate.

FIGURE 1 schematically illustrates the location of ion gun 14 along the path of advance of plexifilament 7 during operation. It may be suspended from the ceiling of chamber 6 or from spinneret device 1 or mounted on brackets to the wall of chamber 6. As shown in FIGURE 1, the necessary vapor pattern flow requires sufficiently open space above gun 14 to permit smooth re-

circulation of vapor over the gun and then along the path of advance. Positioning of ion gun 14 is important to obtain maximum charging efficiency and also to avoid web bunching and flicking which are detrimental to sheet uniformity. "Bunching" is a small pile-up which occurs when a web passing down a target plate is slowed by pinning forces. "Flicking" occurs when fast moving web hits this bundle and flips it away from the target plate, sometimes resulting in hang-up on the needle point 22 and always discharging the web unevenly. Thus, although a short distance between needle point 22 and target plate 13 provides a relatively low voltage requirement to produce a given target plate current, close spacing can only be tolerated if web flicking and bunching is held to a minimum. The problems are particularly acute in the production of sheets from plexifilamentary structures due to the fluffy nature of the plexifilament which makes it particularly susceptible to irregularities caused by non-uniform aerodynamic or electrostatic patterns. Use of a baffle or spinneret shroud helps to spread and thereby dissipate the vapor blast that flashes from the spinneret. A high velocity vapor stream at the collecting surface otherwise disarranges deposited webs and causes them to roll. Thus a smooth pattern of vapor flow within chamber 6 is important to assist in the orderly forwarding of plexifilament 7 along its path of advance from spinning orifice 5 to collecting surface 9 while avoiding interference with the plexifilament at the collecting surface. Equipment shapes to promote these aerodynamic desiderata are important for efficient and high speed operation. For instance the trailing edge of target 13 is shown in FIGURES 1 and 5 to terminate in a straight thin edge, such a shape being important to promote smooth vapor flow despite the electrical discharge known to be associated with sharp edges. Furthermore, while the housing of ion gun 14 may be of a rectangular box shape as shown in FIGURE 4, it is preferred that, as shown in FIGURE 2, it have a rounded top 23 and present an unbroken flat pin supporting face 24 to the path of advance of the plexifilament.

With reference to the details of construction of the ion guns FIGURE 4 shows one embodiment wherein a row of conducting needles 25 mounted in a housing 26 and protruding from one side 27 thereof are connected, through individual resistors 28, in parallel to a conducting bar 29. Conducting bar 29 has terminals for connecting to high voltage leads at 30 or 31. The resistors 28 and bar 29 are contained within housing 26, shown in FIGURE 4 with the top removed. In operation the top (not shown) is secured to enclose the contained elements. A more preferred gun is illustrated in FIGURE 2. In the embodiment the resistors are housed in a compartment 26' removed sufficiently from the housing supporting needles 25 to avoid interference with the pattern of vapor flow over the top of the gun, i.e. surface 23. Here again, the needles 25 are connected individually through resistors 28 by means of leads 32, in parallel to high voltage terminal connections provided at 33. For convenience in cleaning the conducting needles or replacing damaged or worn needles they may be constructed in such a way that they may be plugged into the ion gun. In this case the needles may have the construction shown in FIGURE 3. Prongs 34 engage the appropriate lead 32 at each needle position. Use of a resistor in series with each needle has been found to provide needle-to-needle current uniformity important in the production of uniform sheet products especially when operating at a low current per needle. Since the use of a prior art ion gun with relatively high current per needle (e.g. 50 to 75 microamperes per point causes "pinning" or clinging of plexifilament web 7 to target plate 13, with subsequent clumping and loss of charge. operation below about 10 microamperes per needle is desirable. With needle separation of about $\frac{3}{8}$ ", between about 6 and 8 microamperes per needle is preferred for depositing a linear polyethylene plexifilament. The ion gun

described herein provides a high impedance circuit to each point so that normal fluctuations in the effective dynamic resistance of corona discharge have little effect on emitted current. In a typical ion gun/target configuration the effective dynamic resistance of corona discharge is about 60 megohms, whereas the resistance placed in series with each point is typically 600 megohms. Use of the resistors makes the needle-to-needle current variations much less sensitive to such factors as point/target spacing, point wear, point contamination, and point-to-point spacing. Power source for ion gun 14 is shown at 35 (FIG. 1).

The position of needles 25 with reference to target plate 13 is important for efficient operation. It will be apparent that the clearance between the needle points and plate 13 should be as small as efficient operation will permit. Generally a clearance of from about 1 to about 2 inches is satisfactory although this will vary with the design and capacity of the particular equipment. It has been found convenient in adjusting positioning of gun 14 opposite to target plate 13 to create a carbon black deposit on target plate 13 by spraying powdered carbon black into the operating area between the plate and the gun. An oval pattern is outlined by carbon deposits opposite each needle indicating the area of electrostatic influence of each needle under the particular conditions employed. Such a pattern of carbon deposit 18 is shown in FIGURE 5. The patterns laid down by single points are centered the same distance apart as the needles, are oval shaped, and have a height of about 2.5 cm. and a width of about 0.6 cm. Smoothest operation of the equipment with uniform laydown occurs when the above-mentioned test patterns are centered at a distance between $\frac{1}{2}$ in. (1.3 cm.) and $\frac{3}{4}$ in (1.9 cm.) from the target bottom. Placement of the ion gun at a point further upstream results in pinning or clinging of the web to the target plate. This results in bunching for an instant, an uneven discharge across the web width, and a falling free of the bunched web to give a nonuniform sheet. In addition, when the gun is aimed further upstream on the target plate, the web charge curve is very abrupt as will be demonstrated hereinafter, making the process more difficult to control. On the other hand if the ion gun is aimed too near the trailing edge of the target plate, secondary ionization will develop at the edge of the target plate providing positively charged ions which will discharge the web unevenly. The web will then collapse and give a ropery strand which in turn gives a nonuniform sheet. In addition the discharged web will not pin well to the belt because of loss of charge. In general the target plate must be of such dimensions that in cooperation with the vapor blast, it will guide the mechanically opened web into the electrostatic charging zone, which zone must be sufficiently removed from possible interfering structures such as spinneret 1 or baffle 8 so that shorting out of the gun does not occur.

After passing through the charging zone, plexifilament 7, as shown in FIGURE 1, is deposited upon a collecting surface 9. The surface illustrated is a continuous belt forwarded by drive rolls 36. The belt is given an opposite electric charge by power source 37 to that imposed on plexifilament 7 in the charging zone. Due to differences in their electrostatic charge, the plexifilament 7 is attracted to surface 9 and clings to it in its arranged condition as a sheet 38 with sufficient force to overcome the disruptive influences of whatever vapor blast may reach this area. Surface 9 carries sheet 38 out of chamber 6 through port 39. Flexible elements 40 across port 39 and also across port 41, which permits reentry of the unloaded continuous belt, assist in retention of vapor within chamber 6. The sheet is then lightly compacted by compacting oil 41 and is collected on wind up roll 42. A conventional solvent recovery unit 43 may be beneficially employed to improve economic operation.

In general, in providing field-assisted laydown of plexifilament 7, three methods may be used to produce strong electrostatic pinning forces on the charged fibers:

- (1) Use of a conductive laydown roll or belt, insulated from ground and raised to a high potential (e.g., 60 kv.).
- (2) Use of a semiconductive laydown belt, in contact with a stationary electrode to which a high potential is connected.
- (3) Use of a porous woven belt of insulating material in contact with an electrode to which a high potential is connected.

The two critical electrostatic requirements placed upon the laydown surface are:

- (1) That an intense electric field can emanate from or be transmitted through the laydown surface toward the approaching fibers.
- (2) That the current produced by neutralization of charged fibers at the laydown surface have a path to ground. In the case of method 3 above, the path is through the interstices of the woven belt, wherein vapor is made conductive as a result of ionization occurring at the laydown surface.

The optimum web charge for a given combination of apparatus, polymer and solvent may be determined by considering the relationship of target plate current versus web charge. Three such relationships are shown in FIGURE 7 for two different ion guns, the equipment being otherwise identical, where one gun is operated during two different polymer flow rates. In each instance the clearance between the points of needles 22 and target plate 13 is 1.5 inches. Other dimensional and operational variations for each of curves A, B and C are listed in Table I below, where polymer flow rate is in pounds per hour and "target aim" is the distance in inches from a point on target plate 13 directly opposite the points of needle 22, to the bottom edge of target plate 13.

TABLE I

Curve	Needles on Gun	Polymer Flow Rate	Target Aim
A-----	19	42	2.5
B-----	25	29	0.5
C-----	25	45	0.5

The necessary data are obtained from spinning experiments wherein the electric potential (in kilovolts) between ion gun and neutral ground is increased incrementally, and the target plate current (observed at 16 in microamperes) and the web charge (in micro coulombs/gram) are determined and recorded. Web charge is determined by collecting web for a stated period (e.g. 8 seconds in a basket coulombmeter.) and weighing. From a consideration of the curves it will be noted that increasing web charge is obtained with increasing target plate current (obtained by increasing potential) until a peak is reached. Thereafter secondary ionization becomes significant and it becomes then increasingly difficult to retain a charge on the web. Secondary ionization is characterized by a glow discharge at the trailing edge of the target plate between the target plate and film-fibrils as they leave the target plate. For uniform web formation it is preferred to operate at a voltage between ion gun and neutral ground that will provide a web charge between about 75% and 100% of peak value under non-secondary ionization conditions. The sharp peak of curve A is typical of the condition wherein needles 22 are aimed too far upstream from the edge of target plate 13. Under these conditions it is relatively difficult to maintain a constant charge on successive portions of the web and across the width of the web. Much more satisfactory control is obtained in situations such as those shown in curves B and C. In all of the curves A, B and C increasing the target plate current above the peak charge level for the web has detrimental effects in that the web tends to pin or cling to the target plate resulting in bunching and flicking which are detrimental to the sheet uniformity and secondary ionization, causes non-uniform loss of charge, uneven collapse, and uneven laydown, the plexi-

filament 7 tending to roll during laydown if it is not properly electrostatically held to the collecting belt. This causes a sheet of poor uniformity and rope-like appearance to be formed.

It is to be noted that very high charge levels are obtained on plexifilamentary webs with very low corona current levels. For example, one can obtain a charge of 5 microcoulombs/gram with only 150 microamperes of current with a 25 point gun. Thus only 6 microamps per corona point are needed. Typical melt spun fibers require a current of 50 to 75 microamperes/point to obtain charges at this level.

The process and apparatus of this invention are particularly useful for flash-spinning in a solvent laden atmosphere. It is desirable to spin into an atmosphere containing less than 30% air (more than 75% gaseous solvent). Spinning of this type must be done with polymer/solvent combinations that separate rapidly on cooling. It is then possible to spin into a closed chamber and have adequate solidification and crystallization of the fiber structure. Thus, a solution of liner polyethylene and trichlorofluoromethane ("Freon-11" of Du Pont) may be spun into a closed chamber, whereupon the web is spread by a baffle or shroud, is charged electrostatically, and is deposited on a moving belt. The gaseous solvent may then be recovered by compression and condensation without difficulty. In the open ventilated cells previously used this would have been much more difficult because of the large amount of air present.

The following example is intended to illustrate the present invention. It is not intended to limit it in any manner.

EXAMPLE I

Two linear polyethylene plexifilamentary webs are flash spun from 13% solid solutions in "Freon-11," two spinnerets in parallel are used each consisting of a letdown orifice and chamber, a final orifice, and a shroud with parallel flat walls which are extensions of two opposite sides of the orifice wall. Spin pack dimensions characteristics are listed in Table II.

TABLE II

Final spinneret orifice diameter	mm	1.1
Letdown orifice diameter	mm	1.27
Shroud length (transverse to flow)	cm	5.1
Distance between shroud walls	mm	1.68
Shroud depth (direction of flow)	cm	1.9

Spinning conditions at each spin pack are listed in Table III.

TABLE III

	No. 1	No. 2
Solution Temp., °C	185	187
Polymer Flow Rate, kg./hr	16.8	20.8
Letdown pressure, p.s.i.g.	950-980	960-985

Each web is then passed over a target plate having a height of 12.7 cm. and a width of 40.7 cm. A negatively charged ion gun is located with needle points 3.8 cm. away from the target plate and on a line 1.3 cm. above the bottom edge of the target plate. The gun used is of the construction illustrated in FIGURE 2. It has 41 needles each attached to a distant 600 megohm resistor by means of a small conducting wire. The conducting wires are electrically insulated from one another and were further encased in a bar of polyacetal resin which supports the needles. The resistors are encased in a box like housing located outside the air stream from the jet. The needles of the ion gun extend 0.48 cm. out of the polyacetal resin face. The needles are 0.14 cm. in diameter at the shank and .007 cm. in radius at the tip. They are mounted on 0.95 cm. centers apart on the bar. Each web is charged as it passes over the target plate and is thereafter pinned to a charged collecting surface, the web from one spinning position being deposited upon the already formed and collected web from the other. The weight and uni-

formity characteristics of the sheet products is shown in Table IV for various plate current readings.

TABLE IV

Target Plate Current, Microamperes	Sheet Weight, oz./yd. ²	Local Uniformity, ¹ oz./yd. ²
150	2.5	0.293
125	2.7	0.292
100	2.6	0.331

¹ Standard deviation of one-inch diameter circles.

As target plate current is lowered, pinning becomes progressively looser. At no time, however, is sheet lost. Although erratic looping up of webs from the laydown surface is observed at levels of 30 microamperes and lower, sheet rollback, phenomena which occur when the solvent blast from one jet impinging upon a laydown surface interferes with sheet formation by an upstream jet on the collecting surface, does not occur. The collecting surface employed is a revolving (38 meters/min.) drum (0.92 meter diameter) charged positively to 55 kv. The path of advance of the plexifilament to the drum surface is 43.3 cm.

While the present invention has been described with particular reference to the formation of sheet products from plexifilaments of polyethylene, it is obvious that the nature of the polymer, the solvent in which it is dissolved and the particular extrusion equipment is not critical. Many suggested alternatives may be found in U.S. 3,081,519 to Blades and White dated Mar. 19, 1963. While the target plate has been described as presenting a "flat" surface to the path of advance of the web and the ion gun, plate curvatures and other constructions which do not interfere with the smooth flow of gases and the mechanically opened web across the target plate may be used. It is important for avoiding turbulence as the web leaves the target plate, that the trailing edge of the plate be flat. While the flat edge is illustrated to be straight, some curvature may be used provided aerodynamic and electrostatic non-uniformity is avoided.

Mechanical separation of the elements of the web may be accomplished in any manner. A fixed or oscillating baffle is suitable as is a fixed or oscillating shrouded spinneret device or combination of shroud and baffle. Arrangement of the mechanical opening means and target plate in such manner as to prevent recycling vapors from lifting the web away from the plate during its advance is particularly desirable. The combination of oscillatable baffle and plate illustrated in FIGURES 5 and 6 where the target plate surrounds the baffle thereby preventing collection of polymeric material on the top edge of the target.

It is important that the ion gun generate a uniform corona field. The gun illustrated in FIGURES 2, 3 and 4, and described and claimed in U.S. application to Owens filed of even date herewith is well suited for this purpose.

While the system illustrated shows the imposition of a negative charge on the web while it travels its path of advance, and a positive charge on the collecting surface, these polarities may be reversed.

The forwarding mechanism of the collecting surface is not critical. A continuous belt is illustrated in FIGURE 1 and the use of a collecting drum is demonstrated in the example. Other conventional moving surface means can be employed for collecting the web lay down and forwarding it to storage. The surface may be metal, conductive rubber, felt or the like. It will be obvious that more than one extrusion and charging unit can feed the same collecting surface simultaneously to provide overlays or to provide wide sheets by integrally overlapping the edges of adjacent web lay downs. Preferably in such arrangements the spinning and charging units are staggered in their assembly above the collecting surface to avoid aerodynamic interference among the various units.

While it is preferred to operate in a closed chamber as illustrated, it is obvious that a more open arrangement than that illustrated is possible, particularly if shielding

means is provided to prevent interference from extraneous, turbulent drafts. The sheet product either before or after leaving the collecting surface may be subjected to after treatments such as calendering, washing, dyeing or the like. Preferably the finished sheet product is led to a windup for storage although other storage means may be used.

Many equivalent modifications of the above invention will be apparent to those skilled in the art from a reading of the above without a departure from the inventive concept.

What is claimed is:

1. An apparatus for separating and electrostatically charging a fibrous web and forwarding it for deposit on a moving surface, said apparatus comprising spinning means for concomitantly forming a fibrous web and a vapor blast and directing the said web along a path of advance, spreading means to open the fibrous elements of the said web, corona charging means immediately downstream from the said spreading means to maintain the fibrous elements in the open configuration, the said charging means comprising an ion gun and a flat target plate having a thin trailing edge, said target plate and gun being disposed on opposite sides of the said path of advance, the said gun presenting a multiplicity of protruding needles aimed at the said target and near the said trailing edge thereof to provide a field of uniform influence essentially completely upon the said target, the said gun and spinning means being separated to permit the surrounding atmosphere to be drawn over the said gun and to join the vapor blast, collecting surface means to receive the said web, electrostatic charging means to

provide the said surface with a charge opposite in polarity to that generated by the said gun on the said web.

2. An apparatus for separating, electrostatically charging and forwarding a fibrous web, said apparatus comprising: spinning means for concomitantly forming a fibrous web and a vapor blast and directing the web along a path of advance; spreading means positioned in said path of advance for opening the fibrous elements of the web; and corona charging means immediately downstream from said spreading means for maintaining the fibrous elements in the open configuration, said charging means comprising an ion gun and a flat target plate having a leading edge and a thin trailing edge, said gun and said plate being disposed on opposite sides of said path of advance, said gun presenting a multiplicity of protruding needles aimed at said target near said trailing edge thereof to provide a field of uniform influence essentially completely upon said target.

3. The apparatus of claim 2 wherein said spreading means is a baffle, said baffle being oscillating and mounted near the leading edge of and protruding through said target plate.

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WILLIAM J. STEPHENSON, *Primary Examiner.*